The Importance of Physical Activity & Fitness in Maintaining a Healthy Weight from Childhood into Adulthood

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ABSTRACT

Little is known about whether the physical activity and cardiorespiratory fitness levels of healthy weight children who successfully maintain a healthy weight into adulthood are different to those healthy weight children who become overweight as adults. A better understanding of these factors may provide useful insights for obesity prevention strategies, which have had limited success to date. This is of concern because overweight and obesity is increasing in prevalence in Australia and internationally in both children and adults. This prospective cohort study therefore aimed to examine the role of physical activity and fitness in healthy weight maintenance from childhood into adulthood.

Subjects were 2,053 Australian adults examined at age 26-36 years in 2004-5, who were first examined as 7-15 year olds in 1985 as part of a national survey of the health and fitness of Australian children. Body mass index (BMI) was calculated at both time-points from measured weight and height (kg/m^2); healthy weight was defined as a BMI less than internationally accepted cutpoints for overweight in children, and as a BMI<25kg/m^2 in adults. Healthy weight maintainers were healthy weight children who remained healthy weight as adults. Physical activity was estimated from a questionnaire at both time-points and also from pedometers at follow-up. Fitness was estimated from a cycle ergometer test at both time-points (9, 12 and 15 year olds at baseline). Baseline (language spoken at home, parental smoking and parental exercise at baseline) and follow-up (smoking, occupation, education level and marital status) sociodemographic factors, were self-reported.

Key findings were:

- At baseline:
  - 89% of boys and 88% of girls were healthy weight
  - There was little evidence of an association between physical activity and healthy weight in children
  - There was stronger evidence of an association between cardiorespiratory fitness and healthy weight in children
- At follow-up:
  - 37% of men and 59% of women were healthy weight defined using BMI cutpoints; 71% of men and 69% of women were healthy weight defined using waist circumference cutpoints
  - Physical activity and cardiorespiratory fitness were positively associated with being a healthy weight
  - Objective measures (pedometer) of physical activity showed stronger associations with healthy weight than did cardiorespiratory fitness
  - Healthy weight defined using waist circumference demonstrated stronger associations than BMI with physical activity and fitness in men

- Longitudinally:
  - 35% of healthy weight boys and 65% of healthy weight girls remained healthy weight as adults
  - Child and adult BMI were well correlated in females (r=0.51) and males (r=0.47); tracking was weaker in the youngest and oldest males
  - Physical activity showed poor tracking from childhood to adulthood (males: r=0.06, females: r=–0.01 for self-reported activity); fitness tracked more strongly (males: r=0.24; females: r=0.27)
  - The most active children were no more likely to be healthy weight maintainers than the least active (RR 0.77, 95% CI: 0.57-1.02 in males; RR 0.98, 95% CI: 0.84-1.13 in females)
  - The fittest children were no more likely to be healthy weight maintainers than the least fit children (RR 0.93, 95% CI: 0.67-1.29 in males; RR 0.97, 95% CI: 0.81-1.15 in females)
  - There was some evidence that younger participants whose cardiorespiratory fitness increased over time were more likely to maintain a healthy weight than those whose fitness decreased (RR 2.30, 95% CI: 1.21-4.38 in males; RR 2.66, 95% CI: 1.46-4.84 in females)
  - There was also evidence that younger participants whose fitness remained stable over time were more likely to be healthy weight maintainers than those whose fitness decreased (RR 1.77, 95% CI: 0.98-3.20 in males; RR 2.25, 95% CI: 1.34-3.79 in females)

While some limitations were evident in this investigation, in particular measurements at only two points in time, it had many key advantages over previous studies, including its size, duration of follow-up and extensive measures of adiposity, physical activity and cardiorespiratory fitness. Little previous research has investigated factors associated with maintaining a healthy weight, and no published reports have examined this relationship from childhood into adulthood. In doing so, this study has provided insights into the physical activity behaviours and cardiorespiratory fitness levels of healthy weight maintainers.

In conclusion, physical activity and cardiorespiratory fitness appeared to play a minor role in the maintenance of a healthy weight from childhood to adulthood. The strongest associations were observed in younger participants. Associations with fitness were stronger than associations with physical activity, suggesting that imprecision in the physical activity measures may have resulted in an underestimation of the effects. The limited contribution of physical activity and fitness to healthy weight maintenance from childhood into adulthood must be considered in the planning of future obesity prevention strategies. There is still much to learn about the behavioural, biological and genetic characteristics of those who manage to maintain a healthy weight in the current obesity-promoting environment.

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ABS	Australian Bureau of Statistics
ACSM	American College of Sports Medicine
AEC	Australian Electoral Commission
ACER	Australian Council for Education Research
AEE	Activity energy expenditure
AGHLS	Amsterdam Growth and Health Longitudinal Study
AIHW	Australian Institute of Health and Welfare
AOD	Australia On Disc
ASHFS	Australian Schools Health and Fitness Survey
AusDiab	Australian Diabetes, Lifestyle and Obesity Study
BIA	Bioelectrical impedance analysis
BMI	Body Mass Index
BRFSS	Behavioral Risk Factor Surveillance System
CAPANS	West Australia Children and Adolescent Nutrition Survey
CARDIA	Coronary Artery Risk Development in Young Adults
CDAH	Childhood Determinants of Adult Health
CDC	Centers for Disease Control & Prevention
CHIC	Cardiovascular Health in Children study
CI	Confidence Interval
CSA	Computer Science & Applications
DEXA	Dual X-Ray absorptiometry
DLW	Doubly-labeled water
DYSS	Danish Youth and Sports Study
GIS	Geographic Information Systems
HBSC	Health Behaviour in School-aged Children study
ICC	Intraclass correlation
IOTF	International Obesity Task Force
IPAQ	International Physical Activity Questionnaire
IRSD	Index of relative socioeconomic disadvantage
LLS	Leuven Longitudinal Study on Lifestyle, Fitness & Health
LTPA	Leisure time physical activity
METs	Metabolic Equivalents
MRI	Menzies Research Institute
MTI	Manufacturing Technology Incorporated
NDI	National Death Index
NSW	New South Wales
NHANES	National Health and Nutrition Examination Survey
NHLBI	National Heart, Lung & Blood Institute

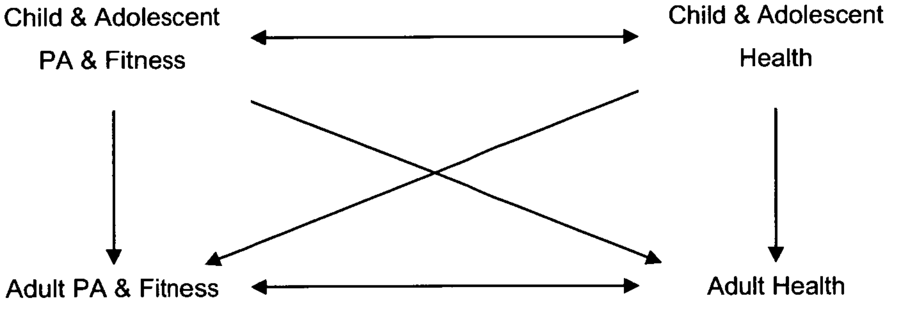
NHMRC	National Health and Medical Research Council
NT	Northern Territory
OECD	Organisation for Economic Cooperation and Development
PA	Physical activity
PE	Physical Education
PR	Prevalence Ratio
PWC_{170}	Physical work capacity at a heart rate of 170 beats per minute
RMR	Resting metabolic rate
RPM	Revolutions per minute
RR	Relative Risk
SA	South Australia
SEIFA	Socioeconomic index for areas
SES	Socioeconomic status
TEE	Total energy expenditure
USA	United States of America
$VO2_{max}$	Maximal oxygen uptake
WA	Western Australia
WC	Waist circumference
WHO	World Health Organisation
WHR	Waist to hip ratio
YRBS	Youth Risk Behaviour Survey

CHAPTER 1 – BACKGROUND

1.1 Introduction

The relationship between physical activity, cardiorespiratory fitness and health in childhood, adolescence and adulthood is complex and multi-directional (Figure 1). For example, it is possible that childhood physical activity influences adult health through three pathways: directly, independent of adult physical activity and child health; indirectly, by influencing child health, which then impacts on adult health; or again indirectly, by influencing adult physical activity, which then impacts on adult health. There is limited data examining the contribution that childhood physical activity and fitness make to adult physical activity and health outcomes, because prospective cohort studies require a large amount of resources, ongoing group maintenance and long periods of follow-up time.

Figure 1: Conceptual model of the relationships between physical activity, fitness & health from childhood & adolescence into adulthood



Source: Blair et al (1989)

1.2 Overweight & Obesity

Overweight and obesity are significant public health concerns because of their deleterious health effects and increasing prevalence. The following section provides definitions of overweight and obesity and discusses their prevalence in children and adults in Australia and internationally. The likely causes of overweight and obesity are discussed, and the consequences of overweight and obesity examined.

1.2.1 Definitions of Overweight & Obesity

Having an excess of body fat, commonly referred to as overweight and obesity, has received much attention over recent years in both the academic literature and the popular media. As well as being regarded as a disease in its own right, obesity is a major risk factor for a number of other diseases, including all-cause mortality, cardiovascular disease, stroke and type 2 diabetes (Visscher and Seidell 2001). Obesity ranks as the fourth highest cause of burden of disease in Australia (Australian Institute of Health & Welfare 1999) and is a growing and significant public health issue.

Overweight and obesity in adults are commonly defined using internationally accepted cut-points of body mass index (BMI), which is calculated using the formula weight (kilograms) divided by height squared (metres^2). Adults with a BMI equal to or greater than 25 kg/m^2 but less than 30 kg/m^2 are considered overweight, while adults with a BMI equal to or greater than 30 kg/m^2 are considered obese (World Health Organisation 1995). Waist circumference can also be used to estimate overweight and obesity, and provides an indication of central adiposity which is known to increase the risk of heart disease independently of BMI (Rexrode, Carey et al. 1998). However, well-accepted definitions for overweight and obesity are yet to be agreed upon. The most commonly used definitions are those developed by the World Health Organisation (WHO), where in men a waist circumference ≥94 cm denotes an increased risk of obesity-related complications (or overweight), while a waist circumference ≥102cm denotes a substantially increased risk of obesity-related complications (or obesity) (World Health Organisation 1999). The corresponding values for women are ≥80cm and ≥88cm, respectively. Waist circumference is a relatively simple and non-invasive procedure suitable for use in large-scale epidemiological investigations. No agreed cutpoints using waist circumference to define overweight and obesity exist for children.

In children, adiposity varies greatly with age and sex so cutpoints for overweight and obesity are more difficult to define. In addition, children have less obesity related disease than adults; the relationship between childhood obesity and adult health outcomes is mediated through adult obesity; and no obvious cutpoints exist because the dose-response relationship between obesity and health outcomes is generally linear (Cole and Rolland-Cachera 2002). Changes in fat mass in childhood occur through changes in the number and in the average size of adipocytes, or fat cells. Growth in the size of adipocytes contributes most to increasing fat mass in infancy, while after infancy increases in the number of adipocytes contribute most to fat mass gain (Knittle, Timmers et al. 1979). Because of these changes, fat mass demonstrates a steep rise during the first year of life then declines, with another rise later in childhood (approximately age 5-10 years), sometimes referred to as the "adiposity rebound". Similar patterns are observed for BMI and skinfold thickness.

In the past, researchers have used national reference data to rank children's BMI according to percentiles. Children at or above the 85th percentile are often defined as "at risk of overweight", while children at or above the 95th percentile are often defined as "overweight". However, internationally accepted cutpoints have recently been developed by pooling international data and linking the adult cut-off points of 25 kg/m^2 and 30 kg/m^2 to BMI centiles for children (Table 1) (Cole, Bellizzi et al. 2000). These new cutpoints, developed by the International Obesity Task Force (IOTF), have many advantages over the use of national population data, most notably allowing the comparison of overweight and obesity prevalence rates across different countries and across different time points. The new cutpoints also allow an internationally standardised approach to the classification of overweight and obesity in children.

Table 1: International cutpoints[a] for overweight & obesity defined using BMI for children aged 9-15 years, by sex

Age (years)	Overweight		Obese	
	Males	Females	Males	Females
9	19.1	19.1	22.8	22.8
9.5	19.5	19.5	23.4	23.5
10	19.8	19.9	24.0	24.1
10.5	20.2	20.3	24.6	24.8
11	20.6	20.7	25.1	25.4
11.5	20.9	21.2	25.6	26.1
12	21.2	21.7	26.0	26.7
12.5	21.6	22.1	26.4	27.2
13	21.9	22.6	26.8	27.8
13.5	22.3	23.0	27.2	28.2
14	22.6	23.3	27.6	28.6
14.5	23.0	23.7	28.0	28.9
15	23.3	23.9	28.3	29.1
15.5	23.6	24.2	28.6	29.3

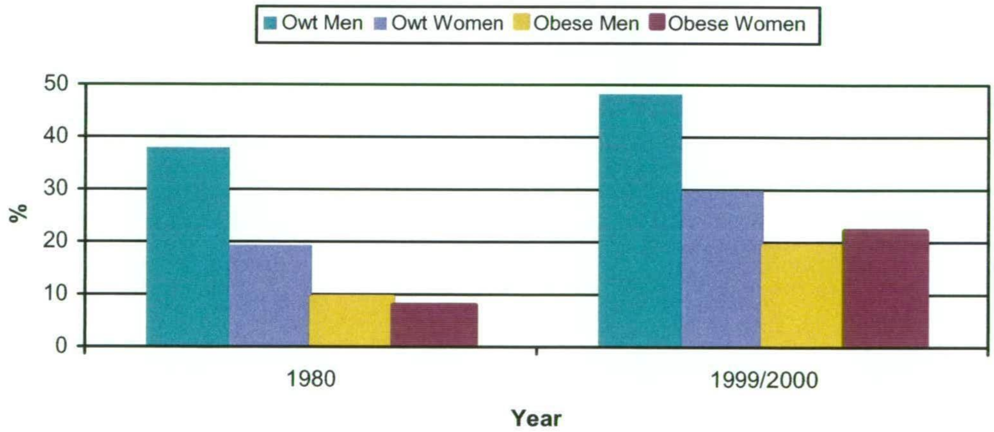
[a] Internationally accepted cutpoints defined to pass through BMI of 25 and 30kg/m^2 at age 18, obtained by averaging data from Brazil, Great Britain, Hong Kong, Netherlands, Singapore and United States (Cole, Bellizzi et al. 2000)

The limitations of using BMI to define overweight and obesity have been acknowledged. Common criticisms include its propensity to overestimate the prevalence of overweight, particularly in men and those with a high proportion of lean body mass such as athletes. This is because BMI does not differentiate between lean body mass and body fat. Correlations between BMI and objective measures of body fat are therefore usually lower than correlations between skinfold thickness measures and objective measures of body fat. Ideal measurements of body fat such as dual x-ray absorptiometry (DEXA), however, are impractical for use in large-scale epidemiological studies, accepted cutpoints have not been well established and estimating body fat from skinfold thicknesses tends to be less reliable. BMI is ideal for use in large epidemiological studies due to its measurement simplicity, minimal cost and low participant burden. Additionally, it has been show to correlate well with more precise measures of body fatness, such as dual x-ray absorptiometry (DEXA) (Daniels, Khoury et al. 1997; Pietrobelli, Faith et al. 1998).

1.2.2 Prevalence of Overweight & Obesity

The prevalence of overweight and obesity in Australian adults has increased over the past few decades (Figure 2). In 1999-2000, the Australian Diabetes, Obesity and Lifestyle Study (AusDiab) investigated the prevalence of overweight and obesity in 11,247 adults aged 25-75+ years (Cameron, Welborn et al. 2003). Overweight (BMI$\geq$ 25kg/m^2 & <30kg/m^2) was evident in 48.2% of men and 29.9% of women. Obesity (BMI$\geq$ 30) was evident in a further 19.3% of men and 22.2% of women, resulting in a total of 67.5% of men and 52.1% of women in Australia above the recommended weight range. This is in contrast to the age-standardised prevalence estimates from the 1980 National Risk Factor Prevalence Survey which examined biomedical and behavioural risk factors in approximately 22,000 Australian adults aged 25-64 years who were living in capital cities (except Darwin and Canberra). In this survey, 37.9% and 19.3% of men and women, respectively, were considered overweight while a further 9.4% of men and 7.9% of women were considered obese (AIHW 2006).

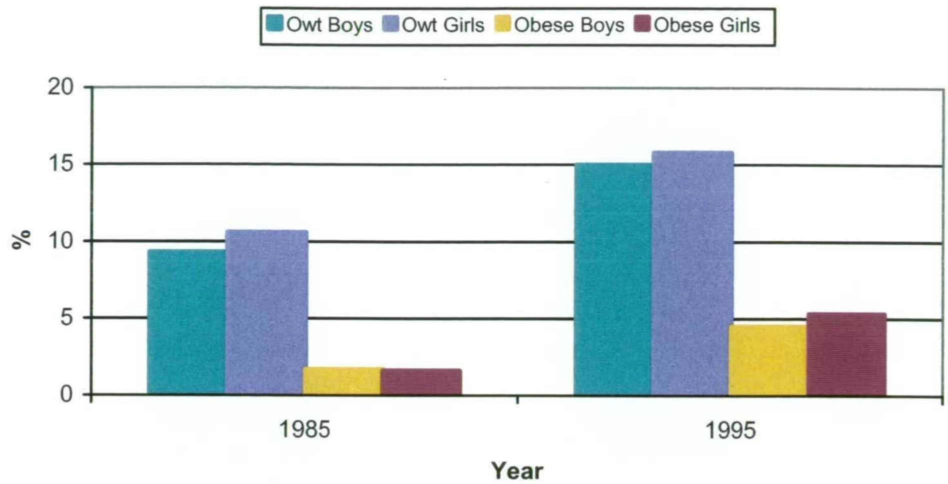
Figure 2: Trends in overweight & obesity in Australian men & women between 1980 & 1999/2000



Similar upward trends have been observed internationally. A higher prevalence of overweight and obesity exists in North America than in Australia. Flegal and colleagues examined data from 4,115 men and women aged 20-74 years involved in the fourth National Health and Nutrition Examination Survey (NHANES) 1999-2000 (Flegal, Carroll et al. 2002). Similar to the AusDiab study, measured height and weight was used to calculate BMI, using the same BMI definitions of overweight and obesity defined previously. Approximately 68% of men and 63% of women were considered overweight, including 28% of men and 34% of women who were considered obese. These figures represent an increase in the prevalence of obesity of 7.3% in men and 8.0% in women from the NHANES III (1988-1994) to the NHANES 1999-2000. While the prevalence of obesity in Canada is lower than that in the USA, similar trends have been observed. In 1981, 9% of men and 8% of women were obese, compared with 14% of men and 12% of women in 1996 (Tremblay, Katzmarzyk et al. 2002). In 1981, 48% of men and 30% of women were deemed overweight, compared with 57% of men and 35% of women deemed overweight in 1996 (Tremblay, Katzmarzyk et al. 2002). Evidence from the UK, based on measured height and weight, also shows similar trends. Between 1986/7 and 2003, the prevalence of obesity increased from 8% in males and 12% in females to 22% in males and 23% in females (Department of Health 1996; Zaninotto, Wardle et al. 2006).

While the prevalence of overweight and obesity in children is lower than in adults, similar upward secular trends have been observed both in Australia (Figure 3) and internationally. In Australian children, data from the 1995 National Nutrition Survey indicated that 15.0% of boys and 15.8% of girls aged 7-15 years were overweight, compared with 9.3% of boys and 10.6% of girls in 1985, and a further 4.5% of boys and 5.3% of girls were considered obese, compared with 1.7% of boys and 1.6% of girls in 1985 (Magarey, Daniels et al. 2001). The reported relative risk of being overweight in 1995 was nearly double that of being overweight in 1985, and the relative risk of obesity in 1995 was more than three times that in 1985 (Magarey, Daniels et al. 2001). Booth and colleagues found similar results when comparing national prevalence data from 1985 to South Australian, New South Wales and Victorian data from 1997 (Booth, Chey et al. 2003). This was in contrast to the much smaller increases found between 1969 and 1985. In fact, in 1969 girls aged 13-15 years had an increased risk of being overweight or obese, compared with girls the same age in 1985, although these differences did not reach statistical significance. In Western Australia, the Children and Adolescent Physical Activity and Nutrition Survey (CAPANS) collected anthropometric data from 2,274 children and adolescents from grades 3, 5, 7, 8, 10 and 11. The prevalence of overweight and obesity in 7-15 year old children was 21.7% of males and 27.8% of females, higher than the prevalence estimated from the 1995 National Nutrition Survey (Magarey, Daniels et al. 2001), most noticeably in girls.

Figure 3: Trends in overweight & obesity in Australian boys & girls between 1985 & 1995



Source: Magarey 2001

While the different definitions used to define overweight and obesity in studies of children make it more difficult to compare results directly, similar trends have been observed in most other developed nations and also in some developing countries. In the USA, data from the NHANES I, II and III surveys enable a comparison of the prevalence of childhood obesity between 1971/4, 1976/80 and 1988/94. In the first NHANES, 3.8% and 3.7% of 6-11 year old boys and girls, respectively, had a BMI greater than the 85th percentile using USA reference data, as did 5.5% and 5.8% of 12-17 year old boys and girls, respectively. By the third NHANES, these rates had increased to 11.2% and 9.1% of 6-11 year old boys and girls, respectively, and 12.2% and 9.4% of 12-17 year old boys and girls, respectively. For the 3,298 children who participated in the most recent NHANES (1999-2000), these figures had increased 30.3% of boys and 27.8% of girls aged 6-11 years, and 30.5% of boys and 30.2% of girls aged 12-19 years having a BMI equal to or greater than the 85th percentile of the sex-specific BMI for age growth charts (at risk of overweight or overweight) (Ogden, Flegal et al. 2002). Sixteen per cent of boys and 14.5% of girls aged 6-11 years and 15.5% of boys and girls aged 12-19 years had a BMI equal to or greater than the 95th percentile of the sex-specific BMI-for-age growth charts (classified as overweight).

In Britain, McCarthy and colleagues compared the prevalence of BMI and waist circumference in 16 year olds between 1977 and 1987 (n=3,784), and 1997 (n=776) (McCarthy, Ellis et al. 2003). In 1977, 7.7% and 8.7% of boys had BMI values and waist circumferences, respectively, exceeding the 91st percentile, compared with 20.6% and 28.5% of boys in 1997 with BMI values and waist circumferences, respectively, exceeding the 91st percentile (BMI reference data were the revised 1990 British reference; waist circumference reference data were the British Standards Institute survey). In 1987, 5.9% of girls had a BMI exceeding the 91st percentile compared with 17.3% of girls in 1997, and 8.8% of girls in 1987 had a waist circumference exceeding the 91st percentile compared with 38.1% of girls in 1997.

In Canada, Tremblay and colleagues analysed data from the 1981 Canada Fitness Survey (n=4,176 participants aged 7-19 years), the 1988 Campbell's Survey of the Well-being of Canadians (n=481 participants aged 7-19 years) and the 1996 National Longitudinal Survey of Children and Youth (n=7,847 participants aged 7-13 years) (Tremblay and Willms 2000). Results demonstrated that the prevalence of overweight among boys increased from 15% in 1981 to 28.8% in 1996 and in girls from 15% to 23.6%. The prevalence of obesity increased from 5% to 13.5% in boys and from 5% to 11.8% in girls.

1.2.3 Causes of Overweight & Obesity

The two main factors involved in the development of overweight and obesity are energy intake (dietary intake) and energy expenditure (physical activity). The role genes play by influencing either energy intake or energy expenditure in the development of obesity is complex. Due to the multifactorial nature of obesity, a number of genes are thought to be involved in its development, particularly those that play a role in variations in energy requirements, fuel utilisation, appetite, satiety, muscle metabolic characteristics and taste preferences. While a recent review concluded that genetic factors explain 50-90% of the variation in BMI (Maes, Neale et al. 1997), genetic variations are unlikely to account for the significant increases in the prevalence of overweight and obesity seen worldwide in both adults and children.

Overweight and obesity result from a positive imbalance between energy intake and energy expenditure. There is some evidence in Australia from repeated monitoring of food and nutrient intake that total energy intake increased by approximately 350kJ/day in adults and by 1,400kJ and 900kJ in boys and girls, respectively, between 1983 and 1995 (Cook, Rutishauser et al. 2001), with similar trends observed internationally (Prentice and Jebb 1995; Harnack, Jeffery et al. 2000; Janssen, Katzmarzyk et al. 2004). However, others have reported decreases in total energy intake in children and adults (Schlicker, Borra et al. 1994; Rolland-Cachera, Deheeger et al. 1996; Heini and Weinsier 1997; Seidell 1997), differences likely related to different measures used.

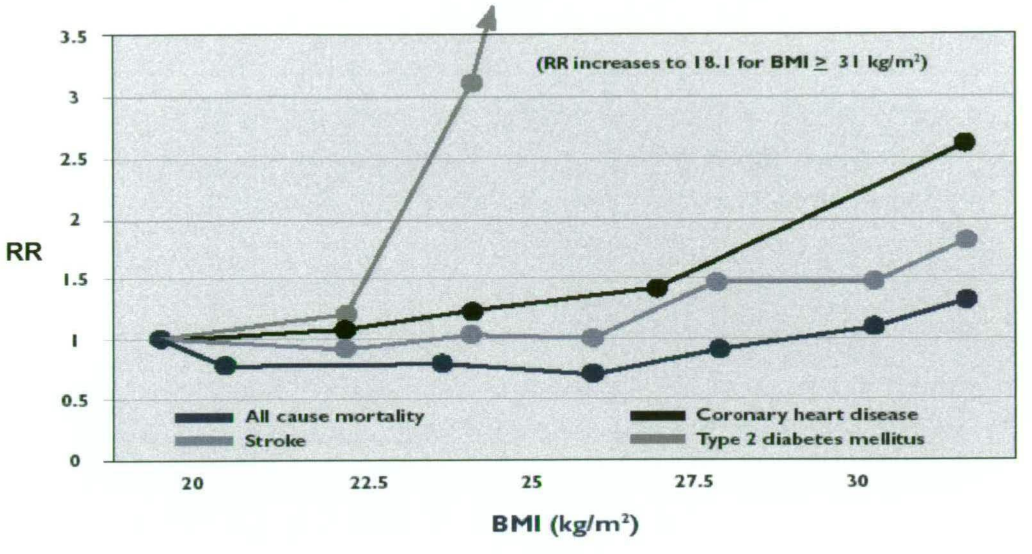
Total energy expenditure (TEE) is comprised of four types of energy expenditure: resting metabolic rate (RMR), the thermogenic effects of food, the energy cost of growth, and activity energy expenditure (AEE). RMR is variable among individuals but makes up the largest component of TEE, consisting of approximately 60-70%. Approximately 5-10% of TEE is needed to metabolise and store food, while the energy cost of growth is very small at most ages (except in the first year of life and during puberty when it increases, but is still small). Little, if anything, can be done to alter these factors. The remaining component is physical activity, a modifiable behaviour that accounts for an estimated 10-30% of TEE.

Because regular monitoring and surveillance of physical activity is not conducted in Australia, empirical evidence for secular trends of the physical activity in Australian adults and children is limited (Molnar and Livingstone 2000). There is some evidence to suggest that adult physical activity has declined and that increases in physical inactivity have occurred (Bauman, Ford et al. 2001). There is also some evidence to suggest that declines in children's physical activity may have occurred, particularly in clearly defined contexts such as active transportation, school physical education and organised sport (Dollman, Norton et al. 2005). These declines however are difficult to quantify due to the different measures used in different surveys, which highlights the need for consistent and regular national monitoring programs. The implications for the apparent disparity in energy balance – increases in energy intake and decreases in energy expenditure – poses significant public health problems.

1.2.4 Consequences of Overweight & Obesity

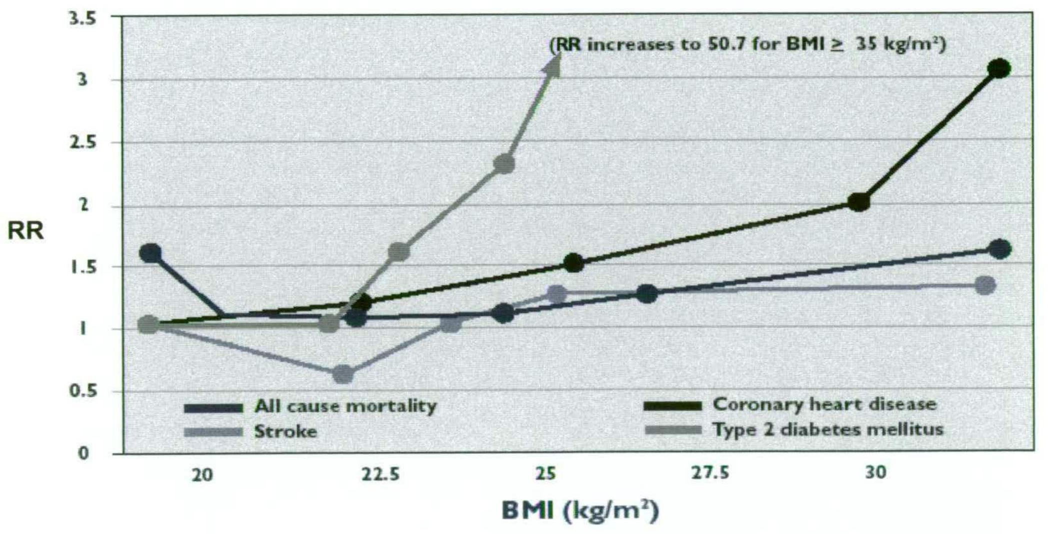
While some have claimed that the health consequences of overweight and obesity have been overstated (Blair and LaMonte 2006; Campos, Saguy et al. 2006), there is still convincing evidence that being overweight or obese increases the risk of negative health outcomes. Data from numerous studies has shown consistent associations between body weight and cardiovascular diseases, type 2 diabetes and stroke. A recent review of the public health impact of obesity concluded that it has a more pronounced impact on morbidity than mortality (Visscher and Seidell 2001). This is demonstrated in findings from the Nurses Health Study (Colditz, Willett et al. 1995; Manson, Willett et al. 1995; Willett, Manson et al. 1995; Rexrode, Hennekens et al. 1997; Huang, Willett et al. 1998) and the Health Professionals Study (Chan, Rimm et al. 1994; Rimm, Stampfer et al. 1995; Walker, Rimm et al. 1996; Baik, Ascherio et al. 2000), two large prospective American cohorts, in Figures 4 and 5.

Figure 4: Age-adjusted relative risk (RR) for different health outcomes among US women in the Nurses' Health Study, by BMI



Source: Visscher et al 2001

Figure 5: Age-adjusted relative risk (RR) for different health outcomes among US men in the Health Professionals Follow-Up Study, by BMI



Source: Visscher et al 2001

Obesity is associated with a number of other diseases and health outcomes, including gall bladder disease, hypertension, dyslipidaemia, insulin resistance, sleep apnoea, some cancers (breast and colon), osteoarthritis and work disability (Visscher and Seidell 2001; National Health and Medical Research Council 2003). In addition to the physical health effects of obesity, there are also psychological and social issues such as social stigma, low self-esteem, reduced mobility and a generally poorer quality of life (Seidell 2005). Additionally, obesity is estimated to contribute to 7% of annual health care costs in the US, 4% in the Netherlands, and 2% in

Australia and France (Colditz 1999). With the increasing prevalence of overweight and obesity, these costs are expected to rise.

Apart from the short-term consequences of overweight and obesity in childhood, such as metabolic and endocrine problems, it has been well established that overweight and obesity track strongly from childhood into adulthood (Serdula, Ivery et al. 1993). Some studies have suggested that obesity in childhood increases the risk of obesity-related morbidity in adulthood (Must, Jacques et al. 1992). There is some additional evidence that obese adults who were also overweight or obese as children are at higher risk for cardiovascular complications than obese adults who were healthy weight children. For instance, data from the Bogalusa and Muscatine studies demonstrate that obese children and adolescents are 8.5-10 times more likely to develop high blood pressure as young adults than non-obese children and adolescents (Lauer and Clarke 1989; Srinivasan, Bao et al. 1996).

1.3 Physical Activity

Physical activity is an important modifiable behaviour that contributes to total energy expenditure and likely plays a major role in the development of overweight and obesity. Physical inactivity is thought to lead to a 1.5 to 2-fold increase in the risk of incident or fatal cardiovascular events (USDHHS 1996). The estimated annual direct cost to the healthcare system in Australia is estimated at around $400 million, not including indirect expenses such as time off work and social costs (Stephenson, Bauman et al. 2000). Physical inactivity is also associated with overall mortality and a number of other chronic diseases including diabetes, some cancers, mental health problems and osteoarthritis (USDHHS 1996). The importance of physical activity in the prevention of a number of chronic diseases was highlighted in 1996 in the Surgeon General's Report on Physical Activity and Health (US Department of Health and Human Services 1996). This key document highlighted the vast amount of evidence linking physical activity to various health and disease outcomes.

1.3.1 Defining & Measuring Physical Activity

The terms physical activity, exercise and fitness are often used interchangeably; however, a clear distinction exists. Physical activity is "bodily movement produced by the contraction of skeletal muscle that increase energy expenditure above the basal level" (Caspersen, Powell et al. 1985). Exercise, on the other hand, is a subset of physical activity that is planned, structured, and repetitive and has as a final or an intermediate objective the improvement or maintenance of physical fitness (Caspersen, Powell et al. 1985). Fitness is different again because it is "a set of attributes that are either health or skill related" and can be measured with specific tests (Caspersen, Powell et al. 1985).

Physical activity can be categorised into a range of different domains, including leisure/sport, household, occupational, transportation, incidental activity and sedentary behaviours (Bauman and Merom 2002). Leisure-time physical activity is usually undertaken in an individual's leisure or discretionary time and the type of activity is generally dependent on personal choice. Household physical activity comprises duties undertaken around the home, including gardening, yard work, domestic duties and caring for children. Occupational activity has traditionally accounted for a substantial amount of energy expenditure; however, technological advances have resulted in many time and energy saving devices that have reduced the amount of energy expended at work. Walking and/or cycling as a form of transport is an important aspect of physical activity that has also seen decline over recent years both in adults (Barengo, Nissinen et al. 2002) and children (Salmon, Timperio et al. 2005). Incidental activity refers to those activities that are a part of an individual's normal daily routine; for example, using stairs at work. Sedentary behaviour includes low energy expenditure tasks such as reading, watching television, computer usage and sitting.

Sedentary behaviour is an important measure of physical inactivity. In a recent study by Hu and colleagues (2003), time spent watching television was positively associated with the risk of obesity and type 2 diabetes. Risk was substantially reduced in individuals who participated in even light to moderate activity. In Australia, the AusDiab study found the influence of television watching time on obesity to be stronger than the influence of physical activity (Cameron, Welborn et al. 2003). Interestingly, those who were in the highest third for physical activity and were also in the highest third for television viewing still showed a high risk for obesity. These findings, however, may be related to a lack of precision in the measurement of physical activity, which will be discussed later in this chapter.

Physical activity has three main dimensions: frequency, duration and intensity. It is important when measuring physical activity to assess these three dimensions to determine which is the most important for particular health outcomes (Wareham and Rennie 1998). For instance, it is important to determine whether the intensity, frequency or duration of physical activity or a combination of two or three dimensions plays the most important role in predicting health outcomes. It is crucial to understand these relationships for public health interventions and recommendations.

The accurate and feasible measurement of physical activity is often difficult in physical activity research, particularly in children and adolescents (Wareham and Rennie 1998). It is important that measures are valid and reliable to accurately and consistently capture physical activity. Measuring children's physical activity poses another significant challenge because children's activity tends to be more sporadic in nature (Welk, Corbin et al. 2000). In addition, children younger than approximately 10 years of age have difficulty completing questionnaires reliably and accurately (Baranowski, Bouchard et al. 1992). Parental proxy-reports are sometimes used in younger children, but again, these may suffer from the same limitations that self-reported questionnaires encounter. Numerous authors have described the benefits and barriers of the multitude of measures available (Pols, Peeters et al. 1998; Wareham and Rennie 1998; Bauman and Merom 2002). These are described briefly here and summarised in Table 2.

Table 2: Summary of common methods used to measure physical activity

Method	Financial Cost	Participant Burden	Accuracy	Time-Cost
Doubly-labeled water	High	High	High	High
Whole body calorimetry	High	High	High	High
Direct observations	Moderate-High	Low	Moderate-High	High
Accelerometers	Moderate	Low	Moderate-High	Low
Pedometers	Low	Low	Moderate	Low
Heart rate monitors	Low	Low	Moderate	Low
Questionnaires	Low	Low	Low	Low-Moderate

The doubly-labeled water technique is considered to be a gold standard for estimating total energy expenditure (Wareham and Rennie 1998). This technique involves the consumption of a quantity of water that is labeled with hydrogen and oxygen isotopes (^{2}H and ^{18}o, respectively) (Prentice 1990). Energy expenditure can be estimated from the difference in the rate of elimination of these two isotopes. While this technique is accurate and non-invasive, it is impractical for large epidemiological studies due to its high cost and the scarcity of the isotopes.

Whole body calorimetry is an alternate gold standard measure. In this process, energy expenditure is measured by collecting all the expired gases from a subject who lives within a sealed room (Murgatroyd, Shetty et al. 1993). Similar to the doubly-labeled water technique, whole body calorimetry is considered highly accurate but is inappropriate for large-scale studies due to its high cost and participant burden. Additionally, it does not necessarily reflect free-living activity because of its laboratory-based nature.

Direct observations provide accurate and comprehensive assessments of physical activity and are not limited by recall or reporting biases (Ainsworth, Montoye et al. 1994). However, direct observation is time-consuming, costly, and intrusive and may result in changes in participants' behaviour in response to being observed.

Accelerometers are small electronic devices that measure accelerations and decelerations of body mass either uniaxially on the vertical plane or triaxially on the horizontal, vertical and mediolateral planes. They record data in real time and are able to measure frequency, intensity and duration of physical activity. While accelerometers are accurate and non-invasive, they are still relatively expensive and the data produced can be difficult to analyse. There is also debate about where thresholds for different intensity levels (i.e. sedentary, light, moderate, vigorous) should be set.

Pedometers provide information on ambulatory activity, are non-invasive and inexpensive. A recent review of validity studies concluded that pedometers correlate well with accelerometers (range: 0.50-0.99, median 0.86), and with direct observation of physical activity (range: 0.42-0.97, median 0.67) (Tudor-Locke, Williams et al. 2002). Correlations with questionnaires were lower, with a median correlation of 0.33 (range: 0.02-0.94). However, pedometers do have some limitations. They do not store data and therefore do not provide any temporal information about physical activity; they cannot measure activity that does not involve locomotion; they do not measure isometric or upper body exercise; and they are not as accurate at very slow speeds (Freedson and Miller 2000; Crouter, Schneider et al. 2003).

Heart rate monitors measure heart rate, and while heart rate does increase with physical activity, it also responds to other factors such as emotional stress, air temperature and air humidity (Montoye, Kemper et al. 1996). Some authors have therefore cautioned against using heart rate monitors to estimate physical activity, particularly in children, because of these reasons (Rowlands, Eston et al. 1997).

Questionnaires provide a subjective assessment of physical activity. Many questionnaires have been developed to measure physical activity, differing in administration mode, target population, time frame assessed and level of detail required (Pereira, FitzerGerald et al. 1997). Questionnaires have the advantage of being inexpensive, and time and energy efficient with relatively little burden placed on participants. They can elicit detailed information about the behavioural aspects of physical activity which objective measures do not assess, and are useful for large epidemiological investigations. However, questionnaires can lack sensitivity, often miss incidental activity, and are open to recall problems such as over or underreporting. Questionnaires generally show low to moderate correlations with more objective measures of physical activity, such as r=0.33 with pedometers, r=0.15-0.24 with accelerometers (Tudor-Locke and Myers 2001; Tudor-Locke and Myers 2001; Schmidt, Freedson et al. 2003).

1.3.2 Physical Activity Recommendations

Since the 1960s, numerous recommendations and guidelines for the required duration, frequency and intensity of physical activity for adults to achieve health benefits have been made by various expert panels and committees (US Department of Health and Human Services 1996). These guidelines and recommendations have been adapted and revised as research into physical activity, fitness and health has evolved.

In Australia, the National Physical Activity Guidelines for Australian adults (Australian Department of Health and Aged Care 1999) make four key recommendations:

- Think of movement as an opportunity, not an inconvenience
- Be active every day in as many ways as you can
- Put together at least 30 minutes of moderate-intensity activity on most, preferably all, days

- If you can, also enjoy some regular, vigorous exercise for extra health and fitness

These guidelines are based on evidence from many studies that have investigated the relationship between physical activity and various health outcomes. The dose-response gradient for the level of physical activity required to achieve health benefits varies between health outcomes. Well-designed studies have shown physical inactivity to be significantly associated with all-cause mortality (Paffenbarger, Hyde et al. 1986; Berlin and Colditz 1990; Leon and Connett 1991; Kaplan, Strawbridge et al. 1996; Leon, Myers et al. 1997), cardiovascular disease (CVD) (Kannel, Belanger et al. 1986; Paffenbarger, Hyde et al. 1986; Shaper, Wannamethee et al. 1991; Leon, Myers et al. 1997), diabetes (Helmrich, Ragland et al. 1991; Manson, Rimm et al. 1991; Manson, Nathan et al. 1992; Wannamethee, Shaper et al. 2000; Hu, Leitzmann et al. 2001), weight status (Klesges, Klesges et al. 1992; Slattery, McDonald et al. 1992; DiPietro, Williamson et al. 1993; Williamson, Madans et al. 1993; French, Jeffery et al. 1994; Ching, Willett et al. 1996; Schmitz, Jacobs et al. 2000; Ball, Owen et al. 2001), and some cancers (Albanes, Blair et al. 1989; Kampert, Blair et al. 1996; IARC 2002; Gregg, Cauley et al. 2003; Lee 2003), in particular, breast (Thune, Brenn et al. 1997; Rockhill, Willett et al. 1999) and colon cancer (Garabrant, Peters et al. 1984; Gerhardsson, Norell et al. 1986; Lee, Paffenbarger et al. 1991; Martinez, Giovannucci et al. 1997).

The US Surgeon General's Report on Physical Activity and Health (US Department of Health and Human Services 1996), the National Institutes of Health Consensus Development Panel on Physical Activity and Cardiovascular Health (NIH 1996), and the Centers for Disease Control and Prevention (CDC) and the American College of Sports Medicine (ACSM) (Pate, Pratt et al. 1995) have also recommended that individuals should accumulate a minimum of 30 minutes of moderate intensity physical activity on most, if not all, days of the week. This is generally interpreted as meaning 150 minutes of physical activity accrued over five days of the week. These guidelines and the Australian guidelines differ from previous recommendations by taking a more flexible, lifestyle-based approach to physical activity, rather than advocating structured timeframes and intensities. They also deviate from most other guidelines in recommending accumulating activity over the course of the day, rather than participating in one continuous bout of activity.

Evidence from training studies such as those conducted by DeBusk and colleagues (DeBusk, Stenestrand et al. 1990) and Ebisu (Ebisu 1985) has contributed to this change in thinking. Debusk and colleagues assessed 32 healthy men aged 51±6 years who participated in an 8-week training program of either 30 minutes of daily exercise training or three 10-minute bouts of exercise training per day. Results suggested that short bouts of moderate-intensity exercise training could significantly increase peak oxygen uptake and may be easier to incorporate into daily life. In a study of 53 untrained male students, Ebisu (Ebisu 1985) allocated subjects to one of four groups: one continuous bout of exercise, two bouts of exercise each half the duration of the first group, three bouts of exercise each one third the duration of the first group, or control. No significant differences in improvements in fitness and high-density lipoprotein (HDL) cholesterol were found between those subjects training for one continuous 30-minute bout compared with those accumulating the same exercise duration over several bouts.

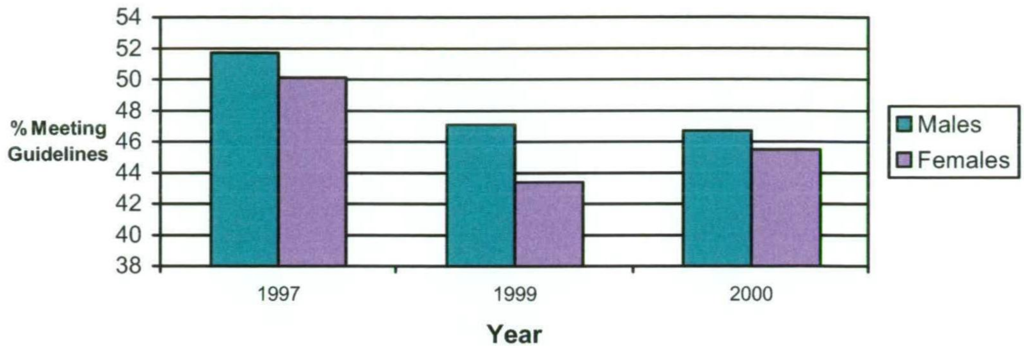
Physical activity guidelines for Australian children have recently been developed. These stipulate that children aged 5-18 years should participate in at least 60 minutes (and up to several hours) of moderate- to vigorous-intensity physical activity every day and should not spend more than 2 hours a day using electronic media for entertainment (e.g. Computer games, Internet, TV), particularly during daylight hours (Australian Department of Health and Aging 2004). The proportion of children meeting these guidelines in Australia is currently unknown.

1.3.3 Physical Activity Participation

Recent concern has been expressed about declining physical activity levels amongst children and adults and the role this may play in the development of overweight and obesity and a range of other chronic diseases. While some countries, such as the US and Canada, have collected physical activity data for many years, limited trend data exist in Australia to support these claims. While long-term empirical evidence for physical activity trends in Australia is limited, adult physical activity data were collected in the recent Active Australia Survey, administered in 1997, 1999 and 2000. Each survey of the physical activity levels of Australian adults aged 18-75 years used identical methodologies (Bauman, Ford et al. 2001). A two-stage sampling procedure was used to randomly select adults proportionally distributed across states and territories. Survey response rates of 61%, 65% and 76% and household response rates of 81%, 89% and 84% have been obtained in the 1997, 1999 and 2000 surveys, respectively. In 1997, 1999 and 2000, 4,824, 3,842 and 3,590 adults, respectively, participated in the survey.

Results suggested that the proportion of Australian adults achieving a total of 150 minutes of physical activity per week over five sessions had declined over the 3 year period. Physical activity participation at a level defined as sufficient for achieving health benefits (150 minutes per week) declined from 63.4% of men and 61.1% of women in 1997 to 57.6% of men and 56.0% of women in 2000 (Armstrong, Bauman et al. 2000). Using a more conservative definition of sufficient physical activity (150 minutes per week and five or more sessions per week), participation declined from 51.7% of men and 50.1% of women in 1997 to 46.7% of men and 45.5% of women in 2000 (Figure 6). These declines were seen across all education levels and age groups, except those aged 60-75 years, where activity levels increased marginally. The number of men reporting no physical activity increased significantly from 13.7% in 1997 to 17.5% in 2000. However, no changes were seen in the proportions of inactive women, with 13.1% of women in 1997 and in 2000 reporting no physical activity in the previous week. The mean number of minutes spent walking, in moderate physical activity and in vigorous physical activity also declined from 1997 to 2000.

Figure 6: Proportion of Australian adults meeting physical activity guidelines in the Active Australia Survey in 1997, 1999 & 2000



Internationally, there is conflicting evidence about the direction of physical activity trends. In Canada, data from six repeated national surveys between 1981 and 2000 found that physical activity increased during the 1980s and 1990s among women and men and for all age, education and income groups (Craig, Russell et al. 2004). In eastern Finland, six independent cross-sectional surveys were conducted between 1972 and 1997 in 30-59 year olds (Barengo, Nissinen et al. 2002). Findings suggested that the proportion of people completely sedentary during leisure time decreased in both men and women, high intensity leisure time physical activity increased in men, and both moderate and high intensity leisure time physical activity increased in women. Data from the USA suggests that the proportion of people meeting the US Surgeon General's Physical Activity Recommendations has reached a plateau (Macera and Pratt 2000).

Evidence on secular trends in children's physical activity is even more limited. However, a recent review attempted to summarise all available evidence in as many areas of daily activity as possible. The authors concluded that there was mounting evidence that physical activity in clearly defined contexts such as active commuting (in many countries), school physical education (particularly in Australia and the USA) and organised sport (particularly in Australia) was declining (Dollman, Norton et al. 2005).

In Australia, the 1985 Australian Schools Health and Fitness Survey (ASHFS) measured self-reported physical activity in a representative sample of Australian children aged 9-15 years (Pyke 1985). While this study aimed to provide baseline data for comparison in future studies, there have been no other national studies assessing children's physical activity in Australia since. Some Australian states have conducted their own children's physical activity surveys.

The New South Wales (NSW) Schools Fitness and Physical Activity Survey in 1997 collected physical activity data from a random sample of 2,026 Year 8 and 10 students in the state of NSW (Booth, Macaskill et al. 1998). Students were deemed to have an adequate level of physical activity if they either: participated in at least 3.5 hours of moderate intensity (3.5-5.9 METS) physical activity over at least five sessions in a normal week (deemed moderately active); or participated in vigorous intensity activities (≥6.0 METS) that required rhythmic use of the large muscle groups at least three times per week for at least 20 minutes per session (deemed as vigorously active) (Booth, Okely et al. 2002). Students who did not fall into these two categories were deemed inactive. These categories were constructed based on the Physical Activity Guidelines for Adolescents, developed in the US (Sallis and Patrick 1994). This survey found that 80.9% and 85.9% of Year 8 and Year 10 boys, respectively, and 80.8% and 77.7% of Year 8 and Year 10 girls, respectively, were considered adequately active during the summer school terms (Booth, Okely et al. 2002). During winter school terms, 75.6% and 84.0% of Year 8 and Year 10 boys, respectively, and 69.4% and 66.0% of Year 8 and Year 10 girls, respectively, were regarded as adequately active (Booth, Okely et al. 2002). These estimates are likely to underestimate the proportion of active children however, given that the authors did not allow combinations of moderate and vigorous physical activity to contribute towards the definition of "active". Girls were found to be less vigorously active than boys, particularly in winter, and there were significant differences between girls from differing cultural backgrounds. The study found no clear differences in physical activity levels between socioeconomic groups or place of residence.

In 2003, the Western Australia CAPANS assessed the physical activity levels of 2,274 children and adolescents from grades 3, 5, 7,8, 10 and 11, with a 60% response rate (Hands, Parker et al. 2004). Most children reported participating in school physical education or school sport. Almost 30% of primary school children and 50% of secondary school children reported no participation in active play. Approximately 50% of the sample reported no active commuting at any time. Primary school boys and girls took on average 12,464 and 10,673 steps per day, respectively, while secondary school boys and girls took on average 13,741 and 11,309 steps per day, respectively. Approximately one in four secondary school boys and one in three secondary school girls reported doing no physical activity in a typical week. Primary school boys and girls spent approximately 2 hours per weekday watching television, while secondary school boys and girls reported about 4 hours per weekday, exceeding the national children's physical activity recommendations of no more than two hours per day (Australian Department of Health and Aging 2004).

In Victoria, the Children's Leisure Activities Study (CLASS) assessed the physical activity of 1,210 5-6 and 10-12 year olds using accelerometers during all waking hours for eight days (Salmon, Telford et al. 2004). On average, 5-6 year olds participated in 4-4.5 hours per day moderate to vigorous physical activity, while 10-12 year olds participated in 2-2.5 hours per day. Nearly all 5-6 year olds achieved met the Australian Physical Activity Guidelines for Children of two hours of moderate to vigorous physical activity per day, while 45% of girls and 70% of boys aged 10-12 years achieved two hours physical activity per day. While these data provide interesting information, cutpoints for intensities of physical activity (sedentary, light, moderate and vigorous) derived from accelerometer data, as well as equations for converting accelerometer counts to hours and minutes, are not yet well-accepted. Additionally, there are few, if any, representative datasets so comparisons with other populations are difficult.

Other Australian bodies have tried to gather information on children's physical activity using alternate methods. In their Monthly Population Survey of households in 2000, the Australian Bureau of Statistics (ABS) asked adults in each household to report cultural and leisure activities of up to three children in their household (Australian Bureau of Statistics 2000). Information about organised sports participation and selected leisure activities (skate boarding, bike riding, television viewing, computer games, art and crafts) was collected on 9,700 children aged 5-14 years. The ABS reported in their 2000 survey that 71% of Australian boys and 58% of Australian girls participated in at least one extracurricular sport (Australian Bureau of Statistics 2000). In 1985, the ASHFS found that nearly 91% of boys and 90% of girls participated in at least one sport in the previous year, and the average number of sports played was just over 2.5 per student (Pyke 1985). While the questions were not identical, this finding suggests a significant decline in sports participation and is cause for concern.

It is difficult to compare participation in physical activity internationally due to varying sampling techniques, data collection methods and culture-specific interpretations of questions. However, it is still interesting to examine the levels of physical activity participation in other countries. Using data from the US Youth Risk Behaviour Survey of high school students, Pratt and colleagues reported that approximately 60% of adolescents participated in regular vigorous physical activity, that boys participated in more vigorous physical activity than girls, that vigorous physical activity declines progressively and significantly with advancing age and that participation in daily physical education has declined since 1991 (Pratt, Macera et al. 1999).

While there is limited trend data available for children's physical activity, a recent systematic review assessed secular trends in children's cardiorespiratory fitness from 1980-2000 (Tomkinson, Leger et al. 2003). This review analysed data from 11 countries which included 55 studies and 129,882 children and adolescents aged 6-19 years whose cardiorespiratory fitness was assessed using the 20 metre shuttle run test. The authors concluded that there had been a significant decrease in the performance of children, with a sample-weighted mean decline of 0.43% of mean values per year. Boys in the USA demonstrated the greatest decline over this time (-2.0% per year), while Australian boys and girls saw significant declines of 0.4-0.8% of mean values per year.

1.4 Physical Activity, Cardiorespiratory Fitness & Adiposity

Even though there have been many studies examining the relationship between physical activity and overweight and obesity in children, there is limited evidence for the existence of an association. Cross-sectional studies tend to observe significant associations, particularly those that use self-report measures. However many of these studies do not use validated or reliable measures of physical activity. Results from prospective studies show little evidence of an association, particularly those that employ objective measures of physical activity. Evidence for a relationship between cardiorespiratory fitness and overweight and obesity is stronger. These findings tend to be consistent regardless of the measure of cardiorespiratory fitness and the measure of adiposity. The differences in findings between cardiorespiratory fitness and physical activity, even when physical activity is measured objectively, have led some others to question whether they act through different biological pathways (Twisk, Kemper et al. 2002). These relationships are explored in more detail in Chapter 3.

In adults, the evidence for an association between physical activity and overweight and obesity from prospective cohort studies is more compelling. Only two studies have used objective measures to assess physical activity, with conflicting results. Prospective studies using self-reported measures generally find mixed results in men, but stronger evidence for an association in women. Two systematic reviews have concluded that there is limited evidence of an association between physical activity and overweight and obesity in adults (Fogelholm and Kukkonen-Harjula 2000; Wareham, van Sluijs et al. 2005). Similar to findings in children, cardiorespiratory fitness generally shows stronger and more consistent associations with overweight and obesity than physical activity. These relationships are explored in more detail in Chapter 4.

1.5 Healthy Weight – A Different Perspective

The majority of research to date has focused on overweight and obesity, and the factors associated with these outcomes. However, there may be interesting and useful lessons to learn from groups who manage to avoid overweight and obesity – those individuals who appear "resilient" to overweight and obesity. In addition, health messages that focus on negative constructs, such as overweight and obesity, may further stigmatise and ostracise overweight or obese individuals. Overweight and obese individuals often have poorer self-esteem (Strauss 2000) and greater levels of disordered eating than healthy weight individuals (Neumark-Sztainer, Wall et al. 2006). It is not yet known what harm may come of labeling children (and adults) as overweight or obese. There also appears to be a paradigm shift towards promoting healthy weight and healthy lifestyles rather than weight loss *per se* (O'Dea 2005). Additionally, a number of researchers have begun attempting to understand the factors associated with healthy weight, weight maintenance or healthy weight maintenance, without prior weight loss (St Jeor, Brunner et al. 1995; St Jeor, Brunner et al. 1997; Ball, Brown et al. 2002; Davison and Birch

2004). This is important because becoming overweight, particularly in adulthood, is common and difficult to reverse. In fact, most weight loss interventions demonstrate little success in the longer term (Jeffery, Drewnowski et al. 2000).

1.6 Aims & Hypotheses

The overall aim of this thesis was to examine the importance of physical activity in the maintenance of a healthy weight from childhood into adulthood. While the specific aims and research questions are detailed in each results chapter, the following key questions are addressed in this thesis:

1. Are active, fit children more likely to be a healthy weight than overweight children? (Chapter 3)
2. Are active, fit adults more likely to be a healthy weight than overweight adults? (Chapter 4)
3. Do adiposity, physical activity and cardiorespiratory track from childhood into adulthood? (Chapter 5)
4. Are active, fit children more likely to maintain a healthy weight from childhood into adulthood? (Chapter 6)

1.7 Summary

Overweight and obesity is a significant public health problem that has increased in prevalence in children and adults in Australia and internationally. Overweight and obesity has short and long-term health consequences. There is evidence from studies mostly conducted in the UK and the USA that overweight and obesity demonstrate strong tracking from childhood into adulthood, and there is some evidence that those obese adults who were overweight or obese as children have greater health risk than those who were healthy weight children.

Physical activity is one side of the energy balance equation that is likely related to overweight and obesity. Clear guidelines for recommended levels of physical activity have been developed, yet many Australian adults are currently not meeting these recommendations. Guidelines for Australian children have recently been developed, but the proportion of children meeting these guidelines is currently unknown. Because of a lack of regular national monitoring of physical activity in Australia, empirical evidence about trends in physical activity is lacking. However, there is some recent evidence to suggest that adults' physical activity has declined in the last decade, and some evidence to suggest that children's physical activity may have declined within clearly defined contexts. .

The difficulties in measuring physical activity accurately and reliably, particularly in children, pose significant barriers to physical activity researchers. Numerous methods exist, but many are expensive, time-consuming and involve high levels of participant burden, and are therefore inappropriate for larger epidemiological studies. Less expensive and less burdensome techniques such as questionnaires are useful for larger studies but often suffer from validity problems and usually fail to collect information on incidental physical activity. Newer methods of measuring physical activity, such as pedometers and accelerometers, offer researchers inexpensive, accurate tools that are simple to administer and have low levels of participant burden.

No research to date has examined the importance of the role of physical activity in maintaining a healthy weight from childhood into adulthood. Examining the childhood factors that predict healthy weight maintenance may provide insights for the development of overweight prevention interventions. The overall aim of this thesis was therefore to determine the importance of the role of physical activity and cardiorespiratory fitness in the maintenance of a healthy weight from childhood into adulthood.

CHAPTER 2 – METHODOLOGY

2.1 Introduction

In the previous chapter, background information was provided on definitions, prevalence, causes and consequences of overweight and obesity. Physical activity was defined, recommended levels of physical activity were described and children and adults' participation in physical activity in Australia and internationally was discussed. The relationship between physical activity, cardiorespiratory fitness and overweight and obesity was examined, and the idea of examining predictors of healthy weight and healthy weight maintenance was introduced. The overall aims and key research questions were stated.

This chapter describes the methods employed in this study. Firstly, the context of the research project is discussed, as well as the aims of the project that this thesis was nestled within. The fieldwork, participants, tracing and recruitment process, and the measures of adiposity, physical activity and cardiorespiratory fitness used are described. The treatment of data are described and lastly, the chapter ends with a summary of the methodology.

2.2 Context

2.2.1 The Childhood Determinants of Adult Health Study

The Childhood Determinants of Adult Health (CDAH) study is a 20-year follow-up of the 1985 Australian Schools Health and Fitness Survey (ASHFS), which cross-sectionally examined the health and fitness of 8,498 Australian children aged 7-15 years. The ASHFS 1985 aimed to obtain benchmark data on the fitness, health and physical performance of Australian schoolchildren aged 7-15 years, which could be used in the future to assess changes. It also aimed to establish a National Fitness Award Scheme and to increase the awareness of fitness and health-related aspects of lifestyle in general, and in schools.

A feasibility study conducted by the Menzies Research Institute (MRI), University of Tasmania, Hobart, Australia, in 2001 aimed to trace 385 individuals from the 1985 ASHFS who attended five schools in Tasmania and Victoria. Of these, 87% were found and 68% agreed to participate in a follow-up study. Based on these figures, the MRI was confident that 80% of the original cohort could be found and that 60% of the original participants would agree to participate in a follow-up study.

The Australian National Health and Medical Research Council (NHMRC) provided funding in 2002 for the MRI to find the remaining participants and to perform follow-up measures. A project team was established, consisting of a project manager, a tracing and recruitment coordinator, a data manager, an administration assistant, a resources and finance officer, and two PhD students (including the author, Verity Cleland (VC)). Numerous casual staff and volunteers were also employed throughout the life of the project to undertake a variety of tasks, including tracing, mail-outs, data scanning, data entry and data double-checking. The Southern Tasmanian Medical Research Ethics Committee approved the project on the 19th December 2000 (H0001852).

Following a strict tracing protocol, a team of tracers commenced searching for the remaining 8,100 participants in 2002 (the tracing process is detailed later in this chapter, section 2.3.2.1). Record linkage was conducted by the National Death Index and the Australian Electoral Commission, historical electoral rolls, electronic telephone and address directories were searched, and other enrolled participants were asked to help locate old classmates.

The CDAH project expected to achieve a number of short- and long-term aims. The short-term aims included testing a number of hypotheses relating to CVD, diabetes and mental health. The long-term aims were to ask the following research questions:

1. Do lifestyle, physical or biological factors in childhood predict risk of coronary heart disease (CHD) in adulthood?
2. Do lifestyle, physical or biological factors in childhood predict risk of type 2 diabetes in adulthood?
3. Is the strength of the association of childhood factors with adult disease stronger than that predicted by the same measures in adulthood?

2.2.2 Contribution of the Author

While the data for this thesis were derived from a larger project (the CDAH follow-up study), the author of this thesis (VC) played an ongoing role as a project team member and contributed in a number of different ways. These included:

- Assisting with tracing and recruitment of participants
- Participating in weekly project team meetings and contributing to routine tasks as requested (for example, contributing to the six-monthly participant newsletter, assisting with mail-outs, etc)
- Sourcing and critically examining physical activity questionnaires, then making recommendations about which, if any, would be most appropriate for use in this study
- Determining which brand of pedometer would be most accurate and reliable for use in this study based on findings from previous research
- Developing a standardised format for participants to record pedometer information (pedometer diary and instructions)

- Developing a protocol for the standardised administration of pedometers at research clinics and follow-up procedures
- Being a member of the data collection team in Tasmania, Northern Territory, northern Queensland and central NSW
- Assisting with general training of field technicians in each state
- Training field technicians in each state to issue pedometers, administer cardiorespiratory and muscular fitness tests, and collect blood pressure measurements (except for Queensland, where the author trained another MRI staff member to train technicians)
- Observing technicians and ensuring they were adhering to protocols approximately 4-6 weeks after initial training in Victoria and NSW
- Coordinating the return of pedometers, which involved contacting participants by telephone if they had not returned their pedometer within three weeks of issue, then re-contacting them on two more occasions 1-2 weeks apart if the pedometer was still not returned. A fourth contact was made by letter asking for the return of the pedometer and pedometer diary, after which follow-up was ceased.
- Assisting with data entry and manually double-checking all scanned and verified pedometer diaries
- Assisting with and providing advice on physical activity and other data management procedures, including the development of cleaning and analysis procedures and protocols

2.3 Participants

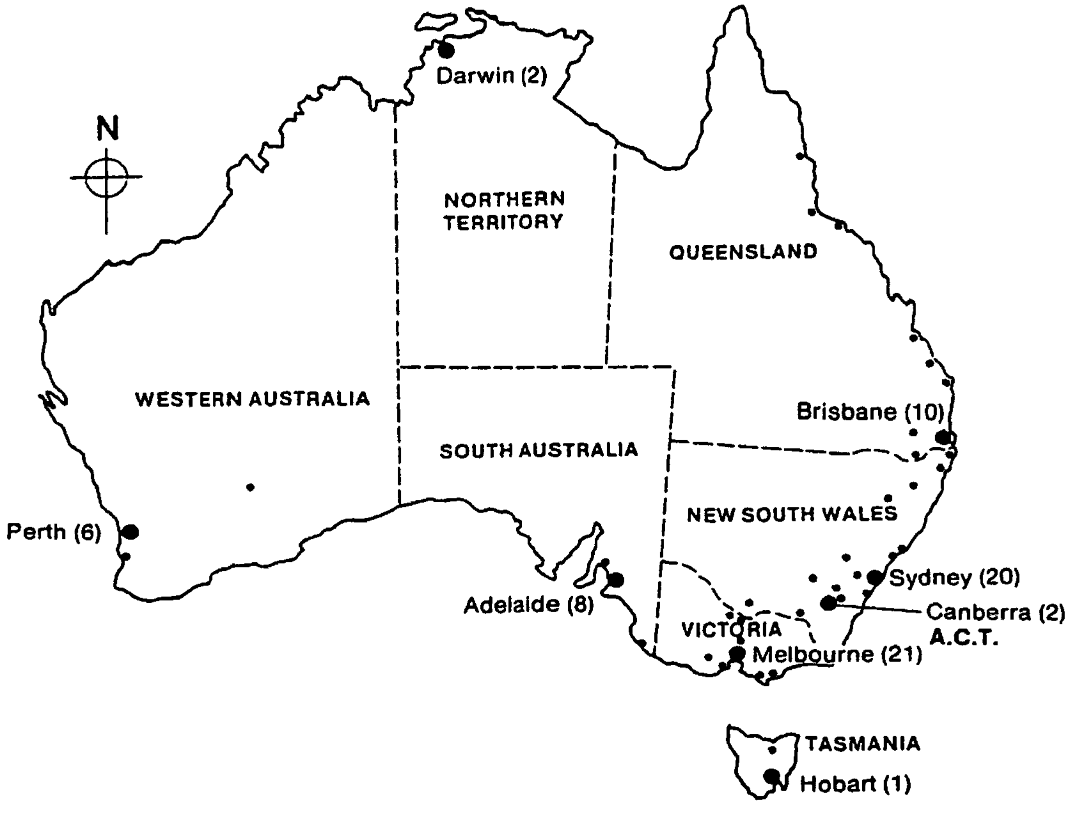
2.3.1 Baseline: The Australian Schools Health & Fitness Survey 1985

In 1985, a two-stage probability sampling process was used to select a nationally representative sample of Australian schoolchildren. The reference population was defined as all students in Australian schools aged 7-15 years on 30 September 1985 (Pyke 1985). The lower age limit of seven years was chosen because below this age, enrolment policies varied between the states and territories, influencing the numbers and ages of children available. The upper age limit of 15 years was chosen because a proportion of children leave school at the age of 16 in Australia, and sampling these children from schools would not be representative of these age groups in the whole population.

The first stage of sampling involved the selection of schools. Schools that were unable to provide groups of 10 students in any age/sex category were not included in the sampling frame. This resulted in the exclusion of 9.9% of primary school students and 3.1% of secondary school students. Schools were chosen with a probability proportional to the number of students aged 10 years in primary schools and 14 years in secondary schools. A replacement school was selected for each sample school in the event of refusal to participate. A company known as the

Australian Council for Education Research (ACER) conducted the sampling procedure. Eligible schools were listed in ascending postcode order to ensure a wide geographical distribution (Dwyer and Gibbons 1994). Starting at a randomly selected postcode and using a constant interval, 109 schools were selected. Twelve of these schools refused to participate and were replaced with another 12 schools (90.1% response rate) (Figure 7).

Figure 7: Distribution of schools surveyed in the ASHFS 1985



Source: Pyke 1985 (Pyke 1985)

The second stage involved the simple random sampling of students. School enrolment information was used to categorise students by age and sex, with 15 students from each age/sex category being systematically selected. These 15 students included five additional students in each age/sex category to allow for non-participation. Only data from 10 students in each age and sex category were used. Approval was granted to contact schools by the State Directors General of Education, and parental and child consent was required for inclusion in the study. A total of 12,578 students aged 7-15 years were invited to participate in the ASHFS. Of these, 8,498 participated, representing an overall response rate of 67.5% (Table 3).

Table 3: Number & proportion of participants & response rates in the ASHFS[a] 1985, by sex & age

Sex & Age	Field & Technical[b]			Questionnaire			Blood Sample		
	N	%	Response rate (%)	N	%	Response rate (%)	N	%	Response rate (%)
BOYS									
7	475	11.0	71.5						
8	490	11.4	75.0						
9	482	11.2	71.1	490	14.6	71.9	371	36.7	77.0
10	492	11.4	77.0	493	14.7	75.7			
11	489	11.4	68.9	482	14.4	66.6			
12	494	11.5	66.0	486	14.5	63.4	349	34.5	70.6
13	465	10.8	65.4	468	14.0	65.0			
14	467	10.9	65.5	472	14.1	66.5			
15	450	10.5	63.3	461	13.8	64.8	291	28.8	64.7
Subtotal	4304	100	69.3	3352	100	67.7	1011	100	70.8
GIRLS									
7	478	11.4	69.6						
8	496	11.9	73.2						
9	487	11.7	72.5	492	15.2	73.8	348	38.3	71.5
10	497	11.9	75.2	496	15.3	73.7			
11	483	11.6	70.5	483	14.9	69.5			
12	489	11.7	65.7	488	15.1	64.7	307	33.8	78.9
13	438	10.5	58.6	437	13.5	59.1			
14	405	9.7	53.6	417	12.9	55.3			
15	407	9.7	56.4	421	13.0	58.5	253	27.9	62.2
Subtotal	4180	100	66.1	3234	100	65.0	908	100	70.9
TOTAL	**8484**		**67.5**	**6586**		**66.1**	**1919**		**70.8**

[a] This table was reproduced from the original ASHFS report (Pyke 1985), which included data for 8,484 participants; however, when the dataset came into the possession of the MRI, data from a further 14 participants were discovered & were therefore included in this thesis

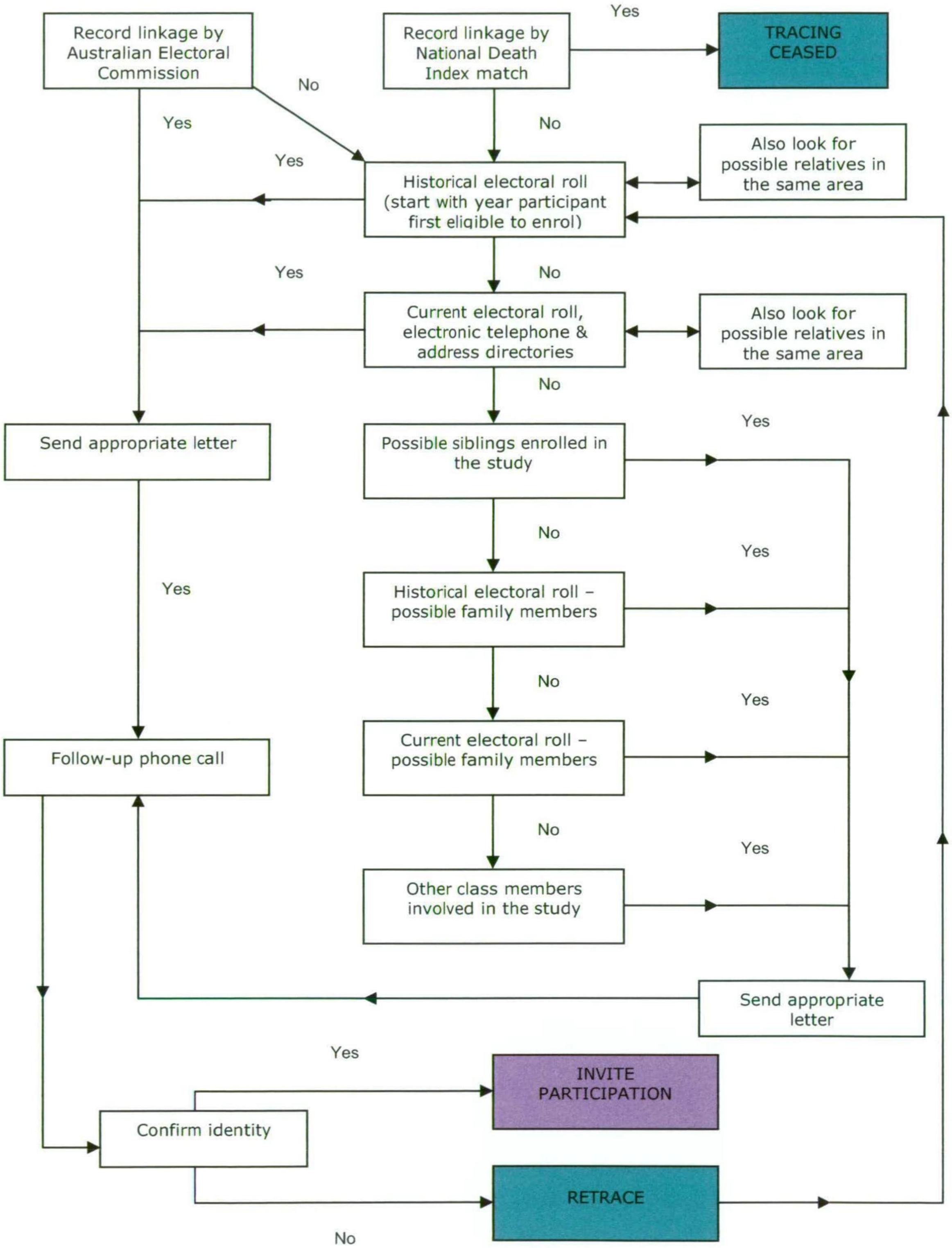
[b] Field and technical tests included height, weight, girths, sit and reach tests, sit-ups, standing long jump, push-ups, a 50m run & a 1.6km run

2.3.2 Follow-Up: The Childhood Determinants of Adult Health Study 2004-2006

2.3.2.1 Tracing and Recruitment

The tracing and recruitment process for the CDAH project began in 2001 with the conduct of the feasibility study (detailed in section 2.2.1). After the success of this study and the attainment of project funding from the NHMRC, the tracing team attempted to contact the remaining untraced ASHFS 1985 participants during 2002-2003. The tracing team adhered to a strict tracing protocol, ensuring that potential participants' privacy was protected and confidentiality was maintained. The tracing procedure is summarised in Figure 8.

Figure 8: The tracing & recruitment procedure used in the CDAH follow-up study



In Australia, it is compulsory to enroll to vote at the age of 18 years on the Australian electoral roll. In 2002, the Australian Electoral Commission (AEC), the body responsible for maintaining the electoral roll, provided address details for approximately 3,500 participants by matching the information provided by the MRI (participant's name in 1985 and date of birth) with their current electoral roll details. These individuals were sent an information package including a letter inviting their participation (detailed below), followed by a phone call within 2-3 weeks if no response was received.

The Australian National Death Index (NDI) also conducted a search to ascertain all deaths until 31 December 2001. Results from this search provided 92 "matches", although only 84 were correct. Tracing of these participants was terminated. Research assessing the accuracy of the NDI has found that it displayed 93.7-95% sensitivity for the identification of known deaths (Powers, Ball et al. 2000; Magliano, Liew et al. 2003). A further four participants are known to have died after the NDI search was conducted.

For those potential participants whose details were not matched by the AEC, the tracing team used a combination of methods in an attempt to trace either the potential participant or members of their family. Historical electoral rolls available in the public library were examined from the year the potential participant turned 18 years and onwards. Current and historical electoral rolls were also searched for potential family members still living in the same area as the participant in 1985. Australia On Disc (AOD) is an electronic database provided by a company called Dependable Database Data and is mainly used for direct marketing. This database contains names, addresses and phone numbers of individuals that are sourced from freely available publications such as telephone directories, and was used by staff at MRI in an attempt to find participants. This database is useful because it has the capacity to provide the names of individuals living at a specified address, unlike a telephone directory where the name of the individual being sought is required. The White Pages online telephone directory was used, and traced participants were helpful in providing information on others who attended the same school. The study was also publicised through a variety of media, including local newspapers, local radio and local television news.

Potential participants were sent an information package containing an invitation letter (Appendix 1), project information (Appendix 2), a consent form (Appendix 3) and an enrolment questionnaire (Appendix 4). Some individuals completed their enrolment questionnaire and provided verbal informed consent over the telephone. Every six months a newsletter was sent to each enrolled participant to maintain communication and provide information about the progress of the project. Refrigerator magnets were given to participants as a reminder to inform the MRI of any address changes.

2.3.2.2 <u>Response Rate</u>

Of the original cohort, 80.6% (n=6,840) were located and contacted by the tracing and recruitment team, as anticipated by the feasibility study findings. Of these, 75.6% agreed to participate and enrolled in the follow-up study (n=5,170). Data for this thesis includes information collected prior to January 1st 2006 from participants in all states and territories in Australia except Western Australia, the last testing site. Information on the number of participants who completed various components of the study is provided in Table 4. Participants who were not able to attend a health clinic for physical measurements were given a list of alternative participation options, including completing questionnaires and wearing a pedometer. Not all participants completed all components of the study so denominators vary depending on the measure being assessed. More detail is provided in Chapter 4.

Table 4: Number of participants & type of information provided in the CDAH follow-up study

	n	% of Enrolled Sample	% of Traced Sample	% of Original Sample
Attended Clinic	2,053	39.8	30.0	24.2
Pedometers	1,860[a]	36.1	27.2	21.9
PA Questionnaire	2,216	43.0	32.4	26.1
General Questionnaire	2,225	43.1	32.5	26.2

PA: physical activity
[a] This total includes 54 pregnant women were excluded from further analyses

2.4 Fieldwork

2.4.1 Baseline: ASHFS 1985

Nine teams consisting of ten data collectors and a field coordinator were engaged for data collection at baseline. Data collectors were mainly graduate or undergraduate Physical Educators and experienced teachers. Registered nurses with experience in venepuncture conducted all the blood tests. The Project Director conducted six days of training for each data collection team prior to the commencement of data collection. A video of protocols and a procedures manual was also given to each data collector. Two days of training involved pilot testing of children in at least three ages groups in a primary school.

The data collection teams at the participating schools completed all field and technical measures. Indoor tests were performed in a gymnasium or other clear floor area, and included anthropometry, sit and reach, standing long jump, push-ups, sit-ups, lung function, grip strength, shoulder strength and leg strength. Students then completed 50m and 1.6km run tests outdoors after a thorough warm-up. Those students aged 9, 12 and 15 years attended the following day to complete blood pressure and further cardiorespiratory fitness measures.

Trained data collectors administered a questionnaire to all 9-15 year olds in groups of four. The data collectors read instructions to all age groups and worked through the first page of questions with each group. Students were situated so that they could not observe other students' responses and were encouraged to ask questions when unsure about requirements.

A registered nurse organised to collect blood samples in schools from 9, 12 and 15 year olds as soon as possible after the field and technical data collection was complete. Students were asked to fast for 12 hours prior to the blood test and rested for 10 minutes before venepuncture occurred. Approximately 300 students aged 9, 12 and 15 years were transported from the school to a nearby laboratory for underwater weighing and maximal oxygen uptake measurement.

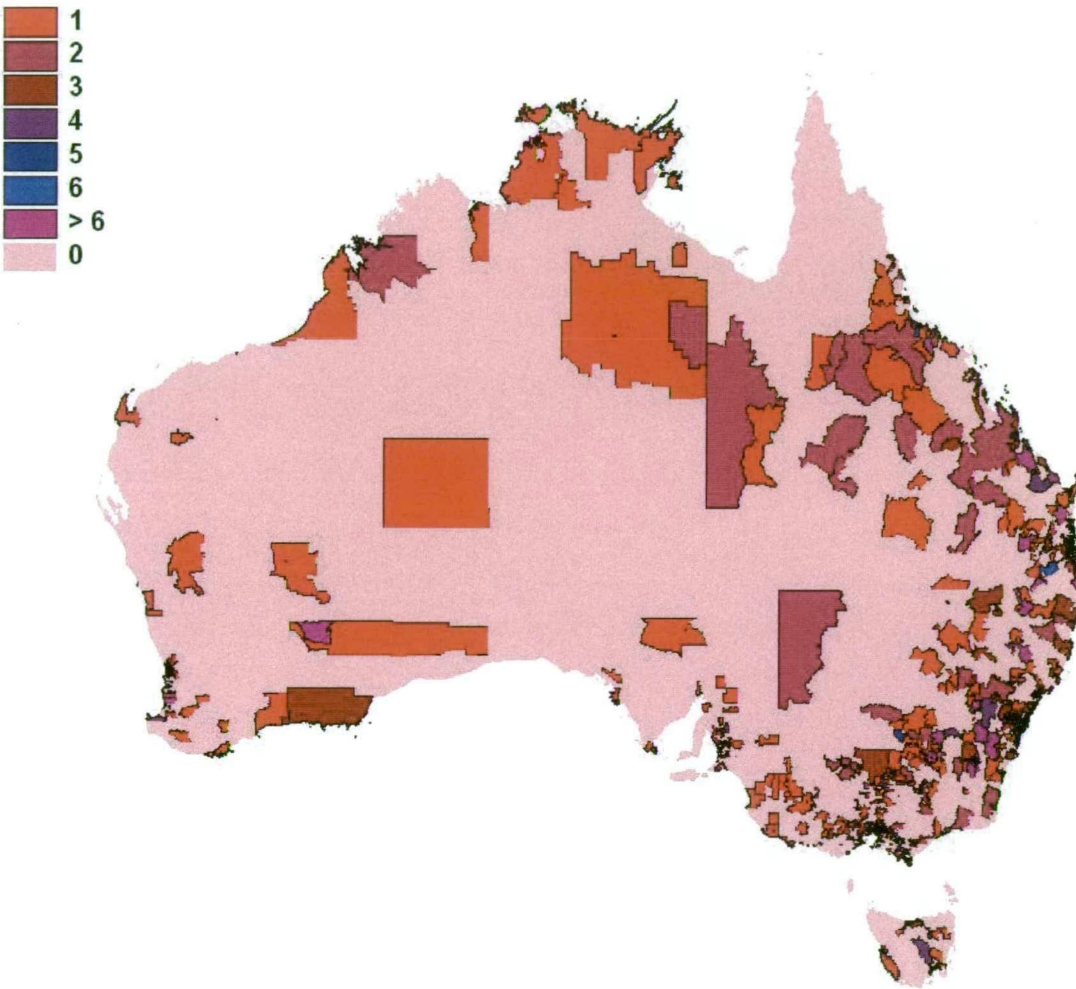
All equipment was checked for accuracy before the data collection process and where possible, during the survey. All equipment was considered robust and only a few minor repairs were required during the survey period.

2.4.2 Follow-Up: CDAH 2004-2006

Five teams consisting of ten data collectors and a field coordinator were engaged for data collection at follow-up. Data collectors were mainly graduates or undergraduates from the health science field. A trained venepuncturist, provided by MedVet Laboratories Inc., South Australia (SA), collected all blood samples. Two days of training for each data collection team was conducted prior to the commencement of data collection. The same person from the MRI conducted the training for each test in each state and territory. In addition to providing background to the study, training involved in-depth explanations of the protocols and procedures associated with each test, as well as practical training.

Participants attended clinics that were held at local schools, community centres, community halls, churches and other similar venues across Australia. Geographic Information Systems (GIS) software was used to map participants' current postcode (Figure 9). Using this information, GIS was then used to determine where clinics would be held so that they were convenient and accessible to as many participants as possible. Two clinics were held in Tasmania (Hobart and Launceston), six were held in Victoria (Flemington, Geelong, Caufield, Numurkah, Narre Warren, Ringwood), three were held in SA (Underdale, Salisbury and Mt Gambier), one clinic each was held in the Northern Territory (NT) (Darwin) and the Australian Capital Territory (ACT), eight were held in Queensland (Townsville, Rockhampton, Gympie, Chermside, Mt Gravatt, Toowoomba, Beenleigh and Broadbeach), and nine were held in New South Wales (NSW) (Armidale, Hornsby, central Sydney, Orange, Newcastle, Dee Why, Bexley, Cronulla and Parramatta). A further three clinics were held in Western Australia (WA) after the data for this thesis had been analysed, and data from these participants were not included in this thesis (n=357).

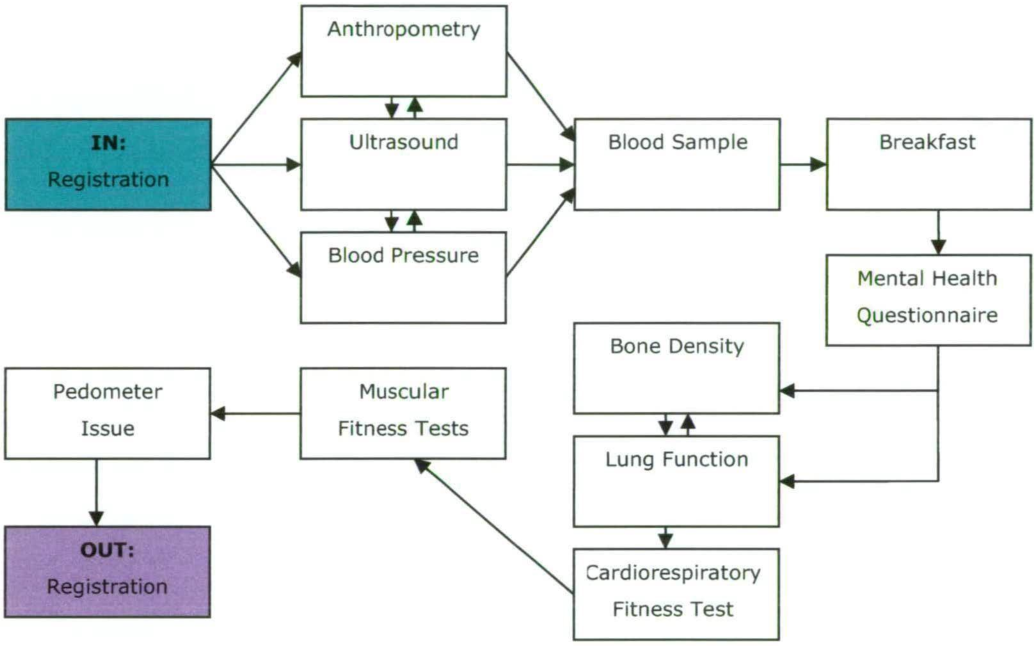
Figure 9: Distribution of participants across Australia in the CDAH follow-up study, as at January 2004



Participants were contacted two months prior to each clinic to arrange an appointment time. Two weeks before their attendance, a set of three questionnaires (general, physical activity and dietary) were mailed to the participant, along with more detailed information about the clinic visit (Appendix 5). Participants were asked to complete the questionnaires and return these at their clinic visit and were asked to fast for 12 hours prior to their appointment. A reminder telephone call was made the day before the appointment.

On arrival at the clinic, signed and witnessed consent was obtained from the participant and completed questionnaires were received. Participants who had not completed their questionnaires were provided with a reply-paid envelope for return at their earliest convenience. While some tests could be completed at any time during the clinic visit, others tests had to be completed sequentially (Figure 10). Firstly, participants could have their blood pressure, anthropometric or carotid ultrasound measurements taken. Once these three tests were conducted, the participant had their blood sample collected, followed by breakfast. After breakfast, participants completed a computer-administered mental health questionnaire, which could be followed by a lung function test, heel bone density measurement or a cardiorespiratory fitness cycle ergometer test. Strength testing had to be done after the cycle ergometer test to ensure muscles were adequately warmed up. Before departure a pedometer was issued, and then participants returned to the registration desk, where it was ensured that they had completed all relevant tests, questionnaires and consent forms. Participants were given a "goody bag" that contained pamphlets, information leaflets, pens, stickers, movie vouchers and various other items donated by local and national businesses. On average, participants spent three hours at the clinic.

Figure 10: Order of testing for the clinic visit procedure for the CDAH follow-up study



All data collected during fieldwork was manually recorded on a clinic record form, which was transported to a central processing unit at the MRI. Clinic record forms, questionnaires and pedometer diaries were scanned electronically into a database using the computer program, Verity TeleForm Version 9. After scanning, all data were manually verified using the TeleForm program, and manually double-checked to ensure accuracy. For quality assurance purposes, the first weeks' data from each state was fast-tracked through the scanning and verifying process to enable detection of differences in average values between the newest data and data obtained previously.

2.5 Measures

2.5.1 Baseline: ASHFS 1985

2.5.1.1 Overview of Baseline Measures

At baseline, data from a range of field, technical, laboratory and blood tests, as well as a questionnaire, were collected. Subsamples were used for more demanding tests. The field tests completed by all participants were height, weight, girths, sit and reach tests, sit-ups, standing long jump, push-ups, a 50m run and a 1.6km run. Technical tests completed by 9, 12 and 15 year olds were muscular strength tests using dynamometers (hand strength, shoulder strength and leg strength), five skinfold thickness measures, blood pressure, lung function and cardiorespiratory fitness using the physical work capacity 170 cycle ergometer test (PWC_{170}). Blood was taken to provide measures of serum cholesterol, triglycerides, high-density lipoprotein, iron, ferritin and transferrin concentrations. Laboratory tests included maximal oxygen uptake ($VO2_{max}$) and under-water weighing on a sub sample of students (n=290). The tests included were based on recommendations made by Coonan and Dwyer (Coonan and Dwyer 1983), with a few minor alterations further detailed elsewhere (Pyke 1985).

Participants aged 9-15 years were surveyed about physical activity, general health, enjoyment of school, academic ability, sleeping patterns, mental wellbeing, smoking behaviours, alcohol consumption, breakfast consumption and demographic information (Appendix 6). This questionnaire was designed to have some elements in common with the Canada Fitness Survey conducted in 1981 (Canada Fitness Survey 1983). Information was also sought about the student's family, including number of brothers and sisters, living arrangements, physical activity and smoking behaviours of parents, parents' country of birth and the language spoken at home. Students completed the questionnaire at school in small groups under the supervision of trained data collectors.

The measures relevant to this thesis – height, weight and waist girths, the student physical activity questionnaire, cardiorespiratory fitness and sociodemographic characteristics – are explained in more detail in this section.

2.5.1.2 Adiposity at Baseline

All children had their body weight measured in kilograms to one decimal point using calibrated medical spring scales. Weight was read to the nearest 0.5kg and repeated until two consecutive measures were the same (known as the repeated score). Height was measured in centimeters to one decimal point (0.1cm) using a rigid metric measuring tape and plastic setsquare (Figure 11). Waist and hip girths were measured in centimeters to one decimal point (0.1cm) using constant tension tape.

Figure 11: Measuring height

BMI was calculated by dividing weight in kilograms by height in metres squared (kg/m^2). Healthy weight was defined as a BMI less than the internationally accepted age- and sex-specific cutpoints-points for overweight and obesity developed by the IOTF, detailed in Chapter 1 (Cole, Bellizzi et al. 2000). These cutpoints are also recommended by the NHMRC for use in population and clinical research in children (National Health and Medical Research Council 2003). Because of the current lack of consensus about a cutpoint for underweight using BMI, a separate category was not defined; the healthy weight group may therefore include some children who were underweight.

2.5.1.3 Physical Activity at Baseline

Numerous studies have assessed the reliability and validity of children's self-reported physical activity. A recent review of these studies found that children aged 9 years and above were able to report physical activity reliably at an acceptable level (retest-reliability correlations range from 0.60-0.98) (Sallis and Saelens 2000). Studies included in this review were those that compared self-reported measures of physical activity to objective measures of physical activity – heart rate monitoring, accelerometers, pedometers or observations. Most surveys showed some evidence of criterion validity, although very few studies tested this in more than one study. While some correlations between self-reported and objectively measured physical activity were low or non-significant, approximately half of the self-administered surveys assessed had validity correlations of 0.50 or above, ranging from 0.07-0.88. For interview-administered surveys, the validity correlations ranged from 0.17-0.72, and for proxy reports, validity correlations ranged from 0.40-0.77, suggesting that these two modes of administration provide little advantage over self-reported physical activity in children. Correlations between self-reported and objectively measured physical activity differed depending on the objective measure used. Correlations were highest when using pedometers (r=0.88) and observations (r=0.72), although these methods were only employed in one validity study each. When self-report was compared with heart rate monitors, correlations ranged from 0.17-0.77 (median: 0.53), and when using accelerometers, correlations ranged from 0.07-0.77 (median: 0.38). The findings from this review suggest that the children in the ASHFS 1985 were likely to report their physical activity to an acceptable level of reliability and accuracy.

Others have tried to establish the validity of physical activity questionnaires in children by comparing reported physical activity with cardiorespiratory fitness, which tends to be well correlated in adults (Kohl, Blair et al. 1988). However, a recent meta-analysis found that while more active children tended to be fitter, children's physical activity only had a modest correlation with fitness (r=0.17) (Trost 1998). It is therefore unclear how useful comparing physical activity with cardiorespiratory fitness is for establishing the validity of a physical activity survey measure. The relationship between children's physical activity and cardiorespiratory fitness is examined in more detail in Chapter 3.

In the ASHFS 1985 student questionnaire, participants were asked to list up to six sports that they had participated in with an organised team, group, club or school, but not for PE at school, during the last 12 months. The responses to these questions represent an estimate of past year participation in extracurricular sport.

Students were asked about all the exercise and sport they had played during the last week. The students were asked how often (how many times last week?), how long (how many hours and minutes were spent each session?), and how much effort (did you huff and puff?) they spent traveling to and from school using a bicycle, traveling to and from school by walking, doing school physical education, doing school sport and doing other activities (students could list up to four activities). For each of these questions, minutes per week spent in these activities were calculated, and each total was summed to provide an estimate of total minutes of past week physical activity. Because intensity of physical activity is highly subjective and likely to vary according to a range of factors, including weight, sex, age and fitness levels, reported intensity was not factored into the estimate of physical activity.

Questions were asked about usual (defined as 3 or more times per week) lunchtime and recess activities (sit and talk to friends, walk around the school, run around playing games/sports, ride/walk home for lunch, train for school sports teams, play sport/games on the oval or in the school grounds, read/study for the next class, nothing much, other). These responses were categorised as sedentary, moderate or vigorous intensity (Table 5). The responses to these questions provide an estimate of the intensity of recess and lunch physical activity. This may be an important estimate of physical activity because unlike school physical education where there is often little choice about the activities undertaken, this type of physical activity is discretionary.

Table 5: Intensity of usual recess & lunchtime activities performed by children aged 9-15 years in the ASHFS 1985

Usual Recess/Lunchtime Activity	Intensity
Sit and talk to friends	Sedentary
Read/study for the next class	Sedentary
Nothing much	Sedentary
Walk around the school	Moderate
Ride/walk home for lunch	Moderate
Run around playing games/sports	Vigorous
Train for school sports teams	Vigorous
Play games/sports on the oval or in the school grounds	Vigorous

Intensity of recess and lunchtime physical activity was combined to form one variable with four categories to give an overall indication of the intensity of discretionary physical activity at school. The categories were developed as presented in Table 6, for example, if a child reported a sedentary behaviour at recess but vigorous behaviour at lunchtime, their discretionary physical activity at school was deemed "moderate-high". These categories take into account the greater length of time allocated to lunch in schools.

Table 6: Categorisation of recess & lunch time physical activities reported in the ASHFS 1985

Recess	Lunch	Overall
Sedentary	Sedentary	Low
	Moderate	Low-moderate
	Vigorous	Moderate-high
Moderate	Sedentary	Low-moderate
	Moderate	Low-moderate
	Vigorous	Moderate-high
Vigorous	Sedentary	Moderate-high
	Moderate	Moderate-high
	Vigorous	High

The physical activity questions provided a range of information about different dimensions and different domains of physical activity (Table 7). It is clear from this table that if a usual measure of total physical activity – total weekly minutes – was the only measure of physical activity to be used, the information collected on extracurricular sports participation and recess and lunchtime physical activity would be lost. Therefore, three physical activity variables – past year extracurricular sport, past week physical activity and discretionary physical activity at recess and lunch times – were derived.

Table 7: Physical activity information gathered from the ASHFS 1985 physical activity questionnaire

Type	Frequency	Duration	Intensity
Extracurricular Sport	✖	✖	✔
Physical Education	✔	✔	✔
School Sport	✔	✔	✔
Walking to/from School	✔	✔	✔
Cycling to/from School	✔	✔	✔
Recess PA	✖	✖	✔
Lunchtime PA	✖	✖	✔

2.5.1.4 Cardiorespiratory Fitness at Baseline

Cardiorespiratory fitness was estimated for children aged 9, 12 and 15 years (n=2,619) from physical working capacity at a heart rate of 170 (PWC_{170}). The test followed standardised procedures (Withers, Davies et al. 1977) and was conducted on a Monark cycle ergometer as a continuous test. Briefly, the workload corresponding to a heart rate of 170 beats per minute was predicted by linear regression from the heart rates recorded at the three submaximal loads (Withers, Davies et al. 1977; Dwyer and Gibbons 1994). To account for lean body mass, this score was then divided by percent body fat estimated from the sum of four skinfold thicknesses (W/kglbm) using the equations of Durnin and Rahaman (Durnin and Rahaman 1967).

2.5.1.5 Potential Confounders at Baseline

Smoking

In the student questionnaire, participants were asked "Have you ever smoked even part of a cigarette?". Response categories were "no", "just a few puffs", "yes, I have smoked fewer than 10 cigarettes in my life" or "yes, I have smoked more than 10 cigarettes in my life".

Parental Behaviours

Children were asked about parental exercise and smoking behaviours. Students were asked, "Does your father exercise regularly (2 or more times a week)?" The examples of jogging, playing sport, doing exercises, going to a gym or doing aerobics were provided. The response options were "yes", "no" or "don't know", and students were asked to list what activity their father did. The same question was asked about students' mothers. Children's responses were classified as "both parents active", "mother active only", "father active only" and "neither parent active". Children who responded "yes" for both their mother and their father were categorised as "both parents active". If the child responded "yes" for mother but "no", "don't know" or had missing data for their father, they were categorised as "mother active only"; "father active only" was similarly defined. If the child reported "no" for one parent and "don't know" or had missing data for the other parent, this resulted in the category "both parents inactive". Children who responded "don't know" or had missing data for both parents were categorised as "incomplete" and were not used in the analyses.

Students were asked whether their mother or father smoked at home ("Does your mother or father smoke at home?"). Response categories were "no", "yes, both", "yes, mother" or "yes, father". These responses were categorised as "both parents smoke", "mum only smokes", "dad only smokes" and "neither parent smokes".

Sociodemographic Information

Participants were asked the open-ended question "In what country were you born?" to determine country of birth. Responses were collapsed into two categories: "Australia" or "a country other than Australia". Students were also asked "Do you speak a language, other than English, at home?" with response options being "yes" or "no". Those that responded "no" were asked to indicate which language they spoke. Responses were collapsed into two categories: "English" or "a language other than English".

Socioeconomic status

Area-level socioeconomic status (SES) was estimated from participants' residential postcode based on the Australian Bureau of Statistics (ABS) socioeconomic index for areas (SEIFA). The SEIFA is a summary index designed to measure different aspects of SES by geographical area, based on questions asked in the Australian population census (McLennan 1998). The ABS classified all Australian postcodes into one of four categories (low, medium-low, medium-high, high) based on an index of relative socioeconomic disadvantage (IRSD) score, such that approximately 25% of Australia's population falls into each of the four IRSD categories in the 1986 census (Social Science Data Archives 1998). In this analysis, the IRSD was matched to the child's residential postcode. In some cases, the child's residential postcode was not reported (n=168) or not able to be matched with a SEIFA code (n=83).

2.5.2 Follow-Up: CDAH 2004-2006

<u>2.5.2.1 Overview of Follow-Up Measures</u>

At follow-up, a range of health and sociodemographic information was collected from participants, aged 26-36 years. This information covered general health, family and medical history, mental and emotional health, current and historical physical activity, current and historical socioeconomic information, social support, reproductive health, lung function, bone density, cardiorespiratory and muscular fitness, blood analysis, adiposity and ultrasound measures of the carotid artery. The measures relevant to this thesis – adiposity, physical activity, cardiorespiratory fitness and sociodemographic factors – are detailed in this section.

<u>2.5.2.2 Adiposity at Follow-Up</u>

Height in centimetres was measured using a Leicester stadiometer to one decimal point (0.1cm) and weight was measured in kilograms to one decimal place (0.1kg) using calibrated digital Heine scales in light clothing with shoes removed. Waist circumference was measured using a Lufkin Thinline Executive 2-metre non-stretch steel tape measure (W606PM) in light clothing. Waist girth was taken at the level of the narrowest point between the lower costal (10^{th} rib) border and the iliac crest. The same qualified anthropometrist (technician qualification Level 1, International Society for the Advancement of Kinanthropometry) trained a staff member in each state to conduct the adiposity measures using a standardised protocol (Appendix 7).

<u>2.5.2.3 Physical Activity</u>

Past Week Physical Activity & Sedentary Behaviour Questionnaire

A multitude of questionnaires to measure physical activity in adults exist (Pereira, FitzerGerald et al. 1997). To determine which questionnaire would be most appropriate for use in the CDAH study, this researcher (VC) conducted a comprehensive assessment of possible physical activity questionnaires. A shortlist of seven of the more common physical activity questionnaires used in Australia was established and are summarised in Table 8. The final questionnaire needed to be brief yet comprehensive and simple for participants to complete. It was important that the questionnaire covered all domains of physical activity (leisure time, occupational, commuting and household/yard work) and gathered information on the frequency, duration and intensity of physical activity (Wareham and Rennie 1998) so that a number of research needs could be met. It was considered useful if the questionnaire was able to provide information on sedentary behaviour, such as sitting or television viewing. The reliability and validity of the questionnaire, and whether the results could be compared nationally and internationally, were also important considerations.

Table 8: Comparison of the number of items, domains, dimensions, disadvantages & recommended usages of physical activity questionnaires commonly used in Australia

Instrument	No. of Items	Where Used	Domains of PA	Frequency/ Intensity/Duration	Advantages	Disadvantages	Useful For...
AAS	8	National PA surveys (1997, 1999, 2000); AusDiab 1999-2000	Walking for LTPA & transport, household (vig), LTPA (mod & vig)	yes/yes/yes	Comparisons with national data possible; quick to complete	Does not cover all domains of PA	Monitoring & surveillance
IPAQ-S	7	International studies	Occupational, commuting, household, LTPA, sitting (*)	yes/yes/yes	Comparisons with international data possible; quick to complete	Does not specifically ask about each domain	Monitoring & surveillance
IPAQ-L	27	International studies	Occupational, commuting, household, LTPA, sitting	yes/yes/yes	Comparisons with international data possible; covers all domains	Longer to complete	Research
BRFSS	11	Developed by CDC in USA; state/ regional samples in WA & SA	Occupational, strength training, transport, household, LTPA (*)	yes/yes/yes	Includes strength training; state/ regional comparisons possible	Does not specifically ask about each domain	Monitoring & surveillance
NHS	9	National health survey 1985, 1995 & 2001/2	LTPA	yes/yes/yes	Comparisons with national data possible	Only covers LTPA, no other domains	Monitoring & surveillance
GPAQ	14	WHO	Occupational, commuting, LTPA, sitting, household	yes/yes/yes	Designed for use in developing countries	National comparisons not possible	Monitoring & surveillance
ERASS	5	Australian Sports Commission 2001	LTPA	yes/yes/no	Comparisons with national data possible	Only covers LTPA, no other domains	Monitoring & surveillance

AAS: Active Australia survey; IPAQ-S: International physical activity questionnaire (short version); IPAQ-L: international physical activity questionnaire (long version); BRFSS: Behavioural risk factor surveillance survey; NHS: National health survey; GPAQ: Global physical activity questionnaire; ERASS: Exercise, recreation and sport survey; LTPA: leisure time physical activity
* Instrument does not specifically ask about each of these areas, rather it asks generic questions according to intensity

Based on these requirements, the self-administered long version of the International Physical Activity Questionnaire (IPAQ-L) was selected to estimate total physical activity in the last week (Appendix 8). The IPAQ is an internationally recognised survey developed by an expert committee for use in adults aged 18-65 years that has an acceptable level of validity and reliability (Marshall and Bauman 2001; Timperio, Salmon et al. 2002). The short (IPAQ-S) and long versions have been reliability and validity tested in 12 countries, and are therefore useful for making international comparisons (Craig, Marshall et al. 2003).

The IPAQ reliability and validity study was conducted in mostly convenience samples at 14 sites in 12 countries, including Australia (Craig, Marshall et al. 2003). To assess reliability, participants completed the selected version of the IPAQ and returned up to one week later to complete the same IPAQ version. Approximately 1,880 and 1,974 participants completed the long and short versions of the IPAQ, respectively. Spearman correlation coefficients for repeatability of the IPAQ-L ranged from 0.46 in rural South Africa to 0.96 in the USA, with a pooled repeatability coefficient of 0.81 (95% CI: 0.79-0.82), indicating very good repeatability. Similar, although slightly lower, Spearman correlation coefficients for repeatability of the IPAQ-S were found. These ranged from 0.32 in rural South Africa to 0.88 in the USA, with a pooled repeatability coefficient of 0.76 (95% CI: 0.73-0.77). The repeatability of the sitting questions on the IPAQ-L also showed generally good levels of agreement. Spearman correlation coefficients ranged from 0.28 in rural Guatemala to 0.93 in Finland and the USA.

To assess the validity of the IPAQ, participants wore a Computer Science and Applications (CSA) Incorporated (now Manufacturing Technology Incorporated or MTI) accelerometer for one week between their first and second visit. At visits one and two, participants completed the same version of the IPAQ. Overall, there was fair to moderate agreement between the participants completing the IPAQ-L (pooled Spearman's coefficient=0.33, 95% CI: 0.26-0.39) and accelerometer data (n=744), and between participants completing the IPAQ-S and accelerometer data (n=781, pooled Spearman's coefficient=0.30, 95% CI: 0.23-0.36). This level of validity is common when comparing objective measures of physical activity to data obtained from physical activity questionnaires (Tudor-Locke, Williams et al. 2002), as physical activity questionnaires generally are not sensitive enough to measure incidental physical activity.

The concurrent (inter-method) validity of the two IPAQ versions was assessed in this study by having participants complete both the short and long versions of the IPAQ. Reasonable agreement was observed between the IPAQ-L and the IPAQ-S, with pooled Spearman coefficients of 0.67 (95% CI: 0.64-0.70).

After conducting these reliability and validity studies, the expert committee recommended that the IPAQ-S be used for international monitoring purposes and that the IPAQ-L be used for research purposes (Craig, Marshall et al. 2003). Based on this recommendation, the slightly more favourable results of the IPAQ-L, and the ability of the IPAQ-L to gather information on both domains (leisure, occupational, transport, yard/household) and dimensions (frequency, intensity, duration) of physical activity, the IPAQ-L was selected to measure past week physical activity in the CDAH study.

The IPAQ-L asks about the frequency, duration and intensity of occupational, commuting, household and yard, and leisure time physical activity. Participants are asked to report those activities that they participated in for at least 10 minutes in duration and examples are provided. For example, participants are asked: "Not counting any walking you have already mentioned, during the last 7 days, on how many days did you walk for at least 10 minutes at a time in your leisure time?" If participants reported no walking in their leisure time, they were asked to skip to the next question. If they reported some walking, they were asked: "How much time did you usually spend on one of those days walking in your leisure time?" The IPAQ-L also assesses sedentary behaviour by asking about time spent sitting in the past seven days and provides examples of sitting activities. For example, "During the last 7 days, how much time did you usually spend sitting on a weekday?"

Data from the IPAQ-L was firstly used to estimate total weekly minutes spent in physical activity. This was done by multiplying the duration and the frequency of each activity within each domain of physical activity. The total number of minutes spent in each domain of physical activity was then summed to provide an estimate of total weekly minutes in physical activity. In addition to overall time spent in physical activity, variables were created for total walking, total moderate physical activity and total vigorous physical activity.

Data from the IPAQ-L was also used to estimate total weekly energy expenditure as metabolic equivalents (METs) per week. Energy expenditure estimates were produced by weighting the reported minutes per week for each activity category by an estimated MET energy expenditure equivalent nominated for each activity category (Table 9). MET estimates were used based on estimates assigned to each physical activity by the IPAQ International Consensus Group (Craig, Marshall et al. 2003). These were based on the updated version of the Compendium of Physical Activities (Ainsworth, Haskell et al. 2000), but because of the generic nature of the self-reported vigorous and moderate physical activity questions, an average of all vigorous and moderate physical activities was used (Craig, Marshall et al. 2003). The weighted METs.mins per week were then summed within and across the activity domains (with the exception of the sitting questions).

Table 9: MET energy expenditure estimates assigned to each self-reported physical activity category in the IPAQ-L

Activity Domain	Activity Type or Intensity	MET Estimate
Occupational	Vigorous	8
	Moderate	4
	Walking	3.3
Transport	Sitting	1
	Walking	3.3
	Cycling	6
Yard/Garden	Vigorous	5.5
	Moderate	4
Household	Vigorous	3
Leisure	Vigorous	8
	Moderate	4
	Walking	3.3
Sitting		1

In addition to the IPAQ-L sitting questions, information about weekly television viewing and computer usage was collected. Questions adapted from work by Salmon and colleagues were used to assess both of these behaviours (Salmon, Owen et al. 2003). Participants were asked to estimate the total time in the last week on weekdays and weekends that they had spent watching television, videos or DVDs when it was the main activity that they were doing. A similar question was asked about computer usage. A one-week test-retest reliability study found that this television-viewing question had an intraclass correlation (ICC) of 0.82 (95% CI 0.75-0.87) and the computer usage question had an ICC of 0.62 (95% CI 0.48-0.73). This represents excellent agreement for the television viewing question and fair to good agreement for the computer use question (Landis and Koch 1977). However, this study was limited by its low response (24%) and high proportion of middle-aged males (77% men, mean age 50.8±13.5 years).

To assess the validity of these sedentary behaviour questions, a 1-week recall of sedentary behaviour compared with a three-day sedentary behaviour log (Salmon, Owen et al. 2003). A community sample of 130 participants recruited from community centres, local newspaper advertisements and workplaces was used (51% women; mean age 38.8±15.0 years). Computer usage was considered to have an acceptable level of validity (Spearman's rank-order correlation=0.60). Reported levels of television viewing in the previous week were significantly correlated with the 3-day sedentary behaviour log, but not at a high level (Spearman's rank-order correlation=0.30, $p<0.01$).

Pedometers

Pedometers have been recommended as the method of choice for measuring physical activity in epidemiological studies (Bassett 2000). While pedometers have a small number of limitations, such as the inability to record time and their insensitivity to activity that does not involve locomotion, isometric exercise or upper body movement (Freedson and Miller 2000), they are an inexpensive, simple and reliable method of measuring physical activity. In a systematic review of 25 studies, Tudor-Locke and colleagues (2002) concluded that there was ample support that the pedometer is a valid option for the measurement of physical activity. This review found good agreement between pedometers and accelerometers (median of reported correlations r=0.86), between pedometers and time in observed physical activity (median of reported correlations r=0.82), between pedometers and different measures of energy expenditure (median of reported correlations r=0.68) and moderate agreement between pedometers and self-reported physical activity (median reported correlation r=0.33). Pedometers are also recommended for measuring walking behaviours (Tudor-Locke and Myers 2001), as low-intensity activities such as walking are less well recalled than moderate or more vigorous activities (Bassett 2000).

The Yamax Digiwalker was selected for use in the current study because it has consistently demonstrated high levels of reliability and accuracy in controlled (Crouter, Schneider et al. 2003; Le Masurier and Tudor-Locke 2003; Schneider, Crouter et al. 2003) and free-living conditions (Schneider, Crouter et al. 2004). The Yamax DW-500 pedometer was found to be the most accurate of five pedometers at recording actual steps taken (Bassett, Ainsworth et al. 1996). The Yamax pedometer also had the smallest between-subject standard deviation. More recently, a similar study compared 10 pedometers and found that the Yamax Digiwalker SW-701 had the highest intraclass correlation coefficient for wear on the right and left sides of the body (ICC: 0.98)(Crouter, Schneider et al. 2003). Also observed was that the Yamax was the only pedometer not to significantly underestimate or overestimate steps at five different speeds. In another study, the intramodel reliability of the Yamax Digiwalker was very high, with a Chronbach's Alpha of 0.99 (Schneider, Crouter et al. 2003). They found the Yamax Digiwalker, along with two other pedometers (which have the same operating principles as accelerometers), were the most accurate of 10 different pedometers at recording number of actual steps. The Yamax model used in these studies has exactly the same operating mechanism as the model used in the current study, but with differing features. In addition to recording steps, the DW-500 and SW-701 have the ability to estimate calories expended and distance walked. The model used in the current study (SW-200) simply records steps, which negates the problem of participants incorrectly recording calories used or kilometers traveled instead of steps taken.

The number of days that participants are recommended to wear pedometers depends on the population being studied and has ranged from 1–14 days, usually including at least one weekend day as these have been shown to differ significantly from weekdays (Tudor-Locke, Bassett et al. 2004). One study reported that a 5-6 day period (including weekend days) was needed for accurate (<5% error) measurement; however, this study was conducted in young men who were purposefully recruited for their varied physical activity pursuits (Gretebeck and Montoye 1992). Studies in chronically ill populations have found fewer days are required because of more stable activity (or inactivity) patterns (Schonhofer, Ardes et al. 1997; Sieminski, Cowell et al. 1997). Most recently, a minimum of three days of measurements, including a

Sunday, was reportedly required to achieve a reliability of 0.80 (Tudor-Locke, Burkett et al. 2005). The authors cautioned that this study was conducted in a self-selected sample of 90 participants and that further investigation is needed to determine whether three days of monitoring is appropriate amongst other populations.

In the current study, participants were instructed to wear a Yamax Digiwalker SW-200 pedometer for seven days, resetting the pedometer at the start of each day (Figure 12). While the person issuing the pedometers differed in different states, all were trained by one of two MRI staff, one of whom developed the pedometer administration protocol (this researcher, VC) and who also trained the alternate instructor (see Appendix 9 for protocol). Quality assessment was conducted on most technicians by the author after approximately four weeks of testing in the larger states (Victoria and NSW). In a pedometer diary (Appendix 10), participants were instructed to record the date, the time they commenced wearing the pedometer, the time the pedometer was taken off, the total steps for the day, time spent active while not wearing the pedometer and the activity they were doing (i.e. swimming), and circumstances that may have affected the pedometer reading (i.e. traveling on rough roads for extended periods of time). Participants were provided with a reply paid postage pack and asked to return their pedometer and pedometer diary as soon as possible. Participants who did not return their pedometer within three weeks of issue received a reminder telephone call from the author (VC). Telephone calls were repeated after three and four weeks if the pedometer had still not been returned. If the pedometer was not returned after five weeks from the date of issue or after three telephone calls, a letter was sent with a new reply paid postage pack.

Figure 12: The Yamax Digiwalker

In the current study, a seven-day period was used to estimate daily steps. Keeping a diary and resetting the pedometer the next day has been found to be a relatively simple and effective method of recording steps among 40-80 year old adults (Tudor-Locke and Myers 2001). It is recommended that extended periods of automobile travel be noted and corrected for as it may cause an overestimation of the number of steps taken (Schonhofer, Ardes et al. 1997), therefore provision was made for participants to record this in the pedometer diary. The average number of hours the pedometer was worn was calculated from the start and end times recorded by participants. A minimum of eight hours wear time was required for daily records, and a minimum of four days readings was required per participant (more detail is provided in Chapter 4).

2.5.2.4 Cardiorespiratory Fitness at Follow-Up

Cardiorespiratory fitness of participants who attended clinics was determined using a sub-maximal graded exercise test to estimate physical working capacity at a heart rate of 170 (PWC_{170}). Data collection staff in each state were trained by one of two MRI staff, one being the author (VC), who also trained the alternate instructor. While the staff who conducted the fitness tests differed in each state, all were trained by one of two MRI staff, including the author (VC). Quality assessment was conducted on most technicians by the author after approximately four weeks of testing in the larger states (Victoria and NSW).

To be consistent with baseline cardiorespiratory fitness measures, the test followed standardised procedures (Withers, Davies et al. 1977). Briefly, after a short warm-up (approximately 2-minutes), participants pedaled continuously on a Monark cycle ergometer (model 828E, Monark Exercise AB, Sweden) for 12 minutes at a cadence of 60 revolutions per minute (RPM). The workload was increased at the end of every four-minute period, so that the heart rate achieved by the participant at the end of the first, second and third workloads were $\geq$115, $\geq$130 and $\geq$145 beats per minute, respectively. Steady-state heart rate was recorded in the last 15 seconds of each workload using a wireless Polar heart rate monitor (Polar Electro Oy, Finland). As a warm down, participants continued to cycle at a decreasing workload after completion of the test for approximately three minutes, after which they were asked to sit quietly while their heart rate was monitored. Recovery heart rate was recorded five minutes after completion of the test.

On a weekly basis, the brake belt contact surface and the brake belt itself were cleaned using a fine abrasive cloth. This was done to prevent build-up of dirt deposits on the brake belt, which can cause the unit to operate unevenly. At each clinic venue, the chain was lubricated, the chain tension checked and static calibration of the pendulum was conducted, according to the manufacturer's instructions. Static calibration involved attaching a known weight (4 kg) to the balancing spring and ensuring that the correct reading was given. If an incorrect reading was given, the scale was adjusted accordingly. Every six months the brake belt was replaced, and every 12 months the chain was replaced. On one occasion during the study, technicians at Victoria University of Technology, Victoria, Australia conducted a dynamic calibration process.

PWC_{170} was estimated by extrapolating the line of best fit from the heart rates recorded at each of the three submaximal workloads. Cardiorespiratory fitness was expressed in relative terms as watts per kilogram (W/kglbm) of lean body mass. Repeatability was not assessed in the current study, but has previously been reported to be as high as 0.92 (Withers, Davies et al. 1977).

2.5.2.5 Potential Confounders at Follow-Up

Smoking

Participants were asked in a general questionnaire (Appendix 11) "Over your lifetime, have you smoked at least 100 cigarettes, or a similar amount of tobacco?". Those who responded "no" were deemed non-smokers. Those who responded "yes" were asked "How often do you now smoke cigarettes, cigars, pipes or any other tobacco products?". Response categories were "daily", "at least once a week (but not daily)", "less often than weekly", or "not at all". Those who responded "daily" were deemed current smokers, while those who responded "at least once a week" or "less often than weekly" were deemed occasional smokers. Those who responded "not at all" were deemed non-smokers.

Sociodemographic factors

Numerous studies have demonstrated associations between current SES and various health outcomes (Lynch, Kaplan et al. 1994; Davey Smith, Hart et al. 1997; Brunner, Shipley et al. 1999; Kuh, Hardy et al. 2002). Indicators commonly used to assess SES include education level and occupation. In the general questionnaire, participants in this study were asked about their highest level of education (primary school, year 7-9, year 10, year 11, year 12, trade/apprenticeship, certificate/ diploma, university degree, higher university degree or other). These categories were collapsed in accordance with the 1995 National Health Survey (Mishra, Ball et al. 2001) into three categories: school only (year 7-9, year 11, year 12), diploma/vocational training (trade/apprenticeship, certificate/diploma), and university (university degree, higher university degree or other). Questions were based on standard questions used in other national surveys (i.e. Australian Bureau of Statistics census). Participants were also asked "What is your main occupation NOW?". Available response categories were manager or administrator, professional, associate professional, tradesperson or related worker, advanced clerical or service worker, intermediate clerical or sales or service worker, intermediate production or transport worker, elementary clerical or sales or service worker, labourer or related worker, or no paid job. Examples were given for each of the 10 response categories. These 10 categories were collapsed into four categories that have been shown to effectively discriminate between groups (Turrell, Hewitt et al. 2003): managers and professionals manager or administrator, professional, associate professional), white collar (advanced clerical or service worker, intermediate clerical or sales or service worker, elementary clerical or sales or service worker), blue collar (tradesperson or related worker, intermediate production or transport worker, labourer or related worker) and not in the labour force (no paid job).

Retrospectively Recalled Socioeconomic Status (SES)

It has been suggested that socioeconomic conditions in early life may play a role in influencing health outcomes in adulthood (Lynch, Kaplan et al. 1994; Kaplan, Turrell et al. 2001; Wamala, Lynch et al. 2001). Very little information about SES in childhood was collected during the ASHFS 1985, with area-level SES estimated from the SEIFA based on children's residential postcode. A questionnaire was therefore developed to assess CDAH participants' childhood SES retrospectively (Appendix 12), based on work by Lynch and colleagues (Lynch 2000). The questionnaire developed for the current study asked participants about the period of their life up until they were 12 years old, as has been done in other studies (Batty, Lawlor et al. 2005). Participants were asked whether they lived with their mother (or another female that was like a mother) and/or father (or other male who was like a father) for most of this time, what their mother and/or father's highest level of education and main occupation was during this time. Response categories were the same as those used to assess the participant's own current SES, as described above, and were collapsed into the same categories.

2.6 Summary

In 1985, 8,498 7-15 year olds were examined as part of the Australian Schools Health and Fitness Survey (ASHFS), a randomly selected nationally representative sample of the health and fitness of Australian children. Twenty years later, 6,840 of these participants were located, with 75.6% of those found agreeing to participate in the Childhood Determinants of Adult Health (CDAH) follow-up study. Data from 2,053 individuals who were re-examined during 2004-5 as young adults aged 26-36 years were used in this thesis.

At baseline and follow-up, height and weight were measured and BMI (kg/m^2) estimated. Waist circumference was measured at both time points. Physical activity was measured in childhood using a self-administered questionnaire that asked about extracurricular sports participation, school sport, school PE, outside school activities, active commuting to and from school, and physical activity at recess and lunchtime. In adulthood, physical activity was measured using the long version of the International Physical Activity Questionnaire (IPAQ-L) and daily steps as measured by pedometers. In childhood, cardiorespiratory fitness was measured using a PWC_{170} cycle ergometer test in 9, 12 and 15 year olds. In adulthood, all participants completed a PWC_{170} cycle ergometer test to estimate cardiorespiratory fitness.

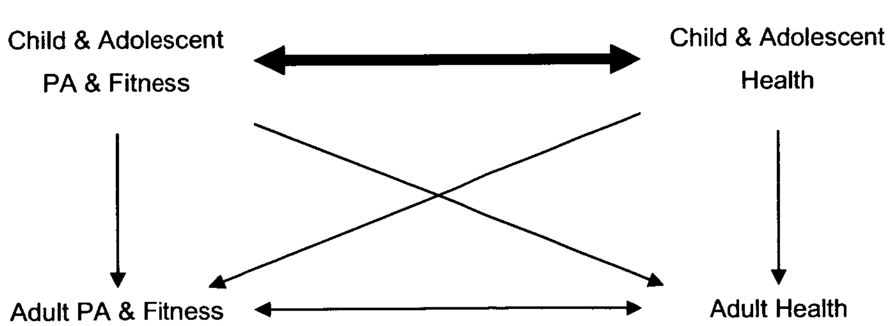
CHAPTER 3 – ARE ACTIVE, FIT CHILDREN MORE LIKELY TO BE A HEALTHY WEIGHT?

3.1 Introduction

Childhood overweight and obesity is a public health issue that has recently received much attention in both the academic literature and in the general community. The escalation of interest in this issue is largely due to increases in the prevalence of overweight and obesity in Australia and internationally. These increases are most likely related to decreases in physical activity and/or increases in total energy intake, as previously discussed. While strong empirical data are lacking due to the absence of a monitoring and surveillance system in Australia, there is some evidence to suggest that children's physical activity has decreased over the past few decades.

The major framework used in this chapter and throughout this thesis is based on a model proposed by Blair and colleagues (1989), as detailed in Figure 13. This model posits that physical activity and fitness have a multidirectional relationship with health. Child and adolescent physical activity and fitness are purported to impact on child and adolescent health, and vice versa. A similar cross-sectional relationship is described in adulthood, where adult physical activity and fitness may impact on adult health and vice versa. The longitudinal relationships described suggest that child and adolescent physical activity and fitness can impact on both adult physical activity and fitness and adult health; similarly, child and adolescent health may impact on adult physical activity and fitness and adult health. In this thesis, Blair's framework has been modified so that the "health" outcome represents weight status.

Figure 13: Conceptual model of the relationships between physical activity, fitness & health from childhood & adolescence into adulthood



Source: Blair et al (1989)

In this chapter, the cross-sectional relationship between physical activity, cardiorespiratory fitness and weight status is explored in further detail in a large, population-based sample of Australian children aged 9-15 years. It is important to do this in order to better understand the relationship between physical activity and weight status in children. This study has the advantage of being a large, population-based sample of randomly selected Australian children with a high response rate. In addition, the physical activity measures include a range of domains of physical activity that may provide a more accurate estimate of children's physical activity than has been used previously.

3.2 Literature Review

The following section provides a detailed and critical review of literature that examines the relationship between overweight and obesity, physical activity and cardiorespiratory fitness in children. It commences with a discussion of the relationship between physical activity and overweight and obesity. This section involves a review of intervention and observational studies that have examined this relationship prospectively and cross-sectionally. The relationship between physical activity and cardiorespiratory fitness is discussed, followed by a discussion of the relationship between cardiorespiratory fitness and overweight and obesity.

3.2.1 Physical Activity & Adiposity in Children

Many studies have examined the relationship between overweight and obesity and physical activity in children and adolescents. Most of these studies are cross-sectional and mostly employ self-reported measures of physical activity with limited reliability or validity properties. This section examines both intervention and observational studies that have aimed to assess this relationship.

3.2.1.1 Intervention Studies in Children

Some studies from the training literature have suggested that physical activity may be more effective at reducing adiposity in those who are already overweight or obese, rather than in normal weight children. For instance, a study of 15 obese boys found that after a 12-week aerobic exercise program there were no significant changes in BMI but total body fat decreased significantly by 4.1±1.8kg ($p<0.05$) (DeStefano, Caprio et al. 2000). Similarly, a four-week training intervention in 81 obese 7-11 year olds was effective at reducing total body fat mass and improving body fat distribution (Gutin and Owens 1999).

In a 14-week South Australian intervention (1983), children in the fitness group (75 minutes of increased intensity physical activity per school day) had significantly lower skinfold measures than those in the control (standard PE) and skill (75 minutes of physical activity per school day with an increased focus on skills in PE) groups ($p<0.05$). Two years later, a random sample of 216 grade 5 students from the same schools underwent the same set of physical measurements as the children in 1978. These children were highly similar to the 1978 children, and unlike children in 1978, the 1980 children had participated in Daily PE for up to two years. The sum of four skinfold measures was significantly lower in the 1980 children than the 1978 children ($p<0.05$), and the proportion of children overweight in 1980 was significantly lower than the proportion in 1978 (20.8% and 30.2% respectively, $p<0.05$).

A recent Cochrane review (Summerbell, Waters et al. 2005) aimed to determine the effectiveness of population-based interventions that focused on diet, physical activity and/or lifestyle support and were designed or had an underlying intention to prevent obesity or further (excessive) weight gain in children. Inclusion criteria for studies included: a controlled design (with or without randomisation); age ≤18 years; non-pregnant; not critically ill; at least 12 week's duration; and not concerned with treatment of eating disorders. The authors identified two long-term (≥1 year) and four short-term interventions (≥3 months and <1 year) that aimed to prevent obesity in children by increasing physical activity. However, two of these short-term interventions included health education components in addition to the physical activity component, making it impossible to distinguish whether the results observed were related to the physical activity component or the health education component, or a combination of the two. In addition, one intervention focused on decreasing television viewing and therefore has not been discussed here. The authors concluded that there was little evidence from well-conducted studies that the interventions employed impacted on the weight status of children to any significant degree.

In Thailand, Mo-suwan and colleagues (Mo-suwan, Pongprapai et al. 1998) conducted a randomised controlled trial in 292 children aged 4-5 years from two kindergartens. The intervention involved 29-30 weeks of a specially designed program that included a 15-minute walk before morning class and a 20-minute aerobic dance session in the afternoon, three times per week. Height, weight and triceps skinfolds were measured pre- and post-intervention. While there were no significant differences in adiposity measures between groups post-intervention, girls in the exercise group tended to have lower average values than girls in the control group, whereas boys in the exercise group tended to have higher average values than boys in the control group.

Project SPARK was a controlled trial of a school-based physical activity program conducted in seven suburban schools in California (Sallis, McKenzie et al. 1993). Complete data, including adiposity measures (height, weight, calf and triceps skinfolds), were available at baseline and follow-up two years later for 549 fourth-grade children. The intervention involved three 30-minute classes per week that focused on conditioning and endurance exercises, cardiovascular fitness and sports skills. Classes were randomised to specialist-led condition, teacher-led condition or a control group with no intervention. Both intervention groups were also involved in a self-management curriculum that aimed to promote behaviour change skills that children could apply to themselves outside school. At each time point there was no significant difference in average adiposity measures between the three groups.

The Promoting Lifestyle Activity for Youth (PLAY) project involved a 12-week intervention for 606 children aged 9-10 years at 35 US schools (Pangrazi, Beighle et al. 2003). Schools were randomised to PLAY only, PLAY and PE, PE only or control groups. The PLAY component involved a daily 15-minute component of teacher-led physical activity. While the intervention appeared to increase physical activity in girls, no significant differences were noted in BMI values across groups.

In addition to the studies identified in the Cochrane review, a small number of shorter interventions were also identified. In the CHIC II intervention, no significant differences were noted in BMI between intervention and control groups, but significant differences were evident for changes in the sum of two skinfold measures (McMurray, Harrell et al. 2002). Children in the combined education (information on nutrition, smoking and exercise) and exercise (30 minutes of aerobic exercise three days per week) group had significantly smaller increases in skinfold thickness than children in the control group ($p<0.001$). However, it is not known whether this was due to the education, exercise or a combination of both. Children in the exercise only group were not significantly different from controls.

A 1-year intervention conducted in WA, Australia, with 971 children aged 10-12 years involved random allocation to either a control group, a fitness only group, a fitness plus school nutrition group, a school nutrition only group, a school plus home nutrition group, or a home nutrition group only (Vandongen, Jenner et al. 1995). The fitness group received six 30-minute classroom sessions aimed at promoting exercise and offered a range of fitness activities, increasing in intensity and duration throughout the intervention. These fitness activities were planned to be implemented for 15 minutes daily throughout the year. Results showed no significant difference in adiposity variables (BMI, triceps skinfold, subscapular skinfold and percent body fat) between the fitness only and control groups.

While evidence from the training literature supports an association between physical activity and adiposity, the results of population-based intervention studies show limited effectiveness. However, in their Cochrane review Summerbell and colleagues conclude that viewing intervention studies as showing no association should be cautioned against, as there are a number of methodological issues that may impact on results (Summerbell, Waters et al. 2005). First, children in intervention groups were compared with children in control groups who were often aware of the study's aims and were involved in physical measurements. It is possible that this awareness and involvement may have impacted on children in the control groups' behaviours, potentially resulting in an underestimation of effect. Second, the authors warn that the majority of these intervention studies have unit of allocation errors, whereby for example individuals were analysed but schools were the unit of allocation. Other issues identified include poor study design, lack of statistical power, short-term goals, lack of studies using a combination of behaviour change and environmental change strategies, and biased sample selection (i.e. convenience samples in high SES areas).

3.2.1.2 Observational Studies in Children

Due to the large number of observational studies examining the association between adiposity and physical activity in children, the literature has been summarised in tables (Appendix 13). Studies are grouped according to study design (prospective or cross-sectional) and measure of physical activity used (objective or self-reported). These tables include information on the country of the study, the authors and year of the study, the number and age of children (by sex if possible), the measure of physical activity, the measure of adiposity, definition of overweight/obesity, significant findings, statistical adjustments, length of follow-up (for prospective studies), and an estimate of the overall effect. A positive (+) overall effect indicates that physical activity is positively associated with adiposity, a negative (-) overall effect indicates a negative relationship, a null (0) effect indicates no association, and an inconclusive (?) effect indicates that mixed results were observed (i.e. a combination of negative and positive associations with no clear trends). As there are a large number of cross-sectional studies, only those studies with a sample size ≥500 and that have assessed children in the age range under investigation in this study (9-15 years) have been included. A summary of the overall findings of these studies is presented in Table 10, more detail can be found in Appendix 13. Where findings were presented separately for boys and girls, these were considered separate studies so the total number of studies presented in the table is larger than that presented in the appendix.

Table 10: Summary of associations observed from prospective & cross-sectional studies that have examined the association between objective & self-reported physical activity & adiposity in children

Overall Association Observed	Prospective Studies		Cross-Sectional Studies	
	Objective PA % (n/N)	Self-Reported PA % (n/N)	Objective PA % (n/N)	Self-Report PA % (n/N)
Nil	40.0 (2/5)	37.5 (6/16)	55.6 (10/18)	34.5 (10/29)
Negative	20.0 (1/5)	18.8 (3/16)	44.4 (8/18)	41.4 (12/29)
Positive	20.0 (1/5)	0.0 (0/16)	0.0 (0/18)	0.0 (0/29)
Inconclusive	20.0 (1/5)	43.8 (7/16)	0.0 (0/18)	24.1 (7/29)

Overall, the findings from these studies provide limited evidence of an association between physical activity and adiposity in children. In general, studies were more likely to have found no association than an inverse association, and many reported inconsistent or inconclusive findings. In studies using objective measures of physical activity, no association was more commonly noted than an inverse association, although findings were equivocal in studies using self-reported measures. It is plausible that the imprecision of self-reported measures, particularly evident in children, are responsible for the inconsistencies seen in these studies. However, the null findings observed in studies using objective measures are unexpected and difficult to explain. It is possible that energy intake may play a more important role than energy expenditure in weight gain, as has been hypothesised in adults (Tataranni, Harper et al. 2003; Ekelund, Brage et al. 2005). Alternatively, it is plausible that a lack of heterogeneity in children's physical activity or adiposity means that small differences are difficult to detect, even when using precise measures.

Few prospective studies of the relationship between adiposity and physical activity have been conducted using objective measures of physical activity, and of those that have, conflicting results are evident (Appendix 13a, Table 1). Most have focused on children younger than 10 years of age and sample size is generally limited. In the USA, no association was found between energy expenditure measured using indirect calorimetry and the doubly-labeled water (DLW) technique and rate of change in fat mass in 75 children aged 3-7 years (Goran, Shewchuk et al. 1998). In contrast, Treuth and colleagues (Treuth, Butte et al. 2003) found total energy expenditure (TEE) measured by calorimetry and the DLW technique in 88 girls aged 8 years was positively associated with percent body fat after two years, although the effect size was small (0.002 increase in percent body fat). Interestingly, there was no association between physical activity level or fitness (measured by maximal oxygen uptake) and percent body fat or fat mass. Conversely, Johnson and colleagues (Johnson, Figueroa-Colon et al. 2000) found fitness (maximal oxygen uptake) but not energy expenditure (measured by DLW) to be associated with a lower rate of increase in adiposity after 3-5 years of follow-up in 115 children aged 4-11 years at baseline. Another study found baseline energy expenditure to be inversely associated with change in percent body fat after 1.6 years, but there was no longer an association with change in total body fat after 2.7 years in 47 girls aged 7-9 years at baseline (Figueroa-Colon, Arani et al. 2000). In an eight-year study of 103 children aged 4 years at baseline, children in the highest tertile of average activity recorded by accelerometers had lower BMI and skinfolds thicknesses at follow-up than children in the lowest tertile of average activity (Moore, Gao et al. 2003). In addition, increases in BMI and skinfold thickness over time were smallest in those children in the highest third of activity, compared with those in the lowest third. The level of follow-up in this study was high, with only three subjects not participating at follow-up after eight years.

Results from prospective studies using self-reported measures of physical activity provide limited support of an inverse association between physical activity and adiposity (Appendix 13a, Table 2). Only one study found an inverse association between adiposity and physical activity in boys (Gordon-Larsen, Adair et al. 2002) and two in girls (Berkey, Rockett et al. 2000; Kimm, Glynn et al. 2005). Five studies saw no association in boys (Beunen, Malina et al. 1992; Maffeis, Talamini et al. 1998; Berkey, Rockett et al. 2000; Kimm, Barton et al. 2001; Kettaneh, Oppert et al. 2005) and two studies saw no association in girls (Maffeis, Talamini et al. 1998; Kimm, Barton et al. 2001). Four studies observed inconclusive or inconsistent results in both boys and girls (O'Loughlin, Gray-Donald et al. 2000; Berkey, Rockett et al. 2003; Bogaert, Steinbeck et al. 2003; Elgar, Roberts et al. 2005), while one study observed inconclusive or inconsistent results in girls only (Kettaneh, Oppert et al. 2005). A number of these studies used measures with questionable validity or reliability (Beunen, Malina et al. 1992; Maffeis, Talamini et al. 1998; O'Loughlin, Gray-Donald et al. 2000; Kimm, Barton et al. 2001; Gordon-Larsen, Adair et al. 2002), while some used measures with acceptable reliability, but questionable validity (Berkey, Rockett et al. 2000; Berkey, Rockett et al. 2003; Bogaert, Steinbeck et al. 2003; Elgar, Roberts et al. 2005; Kettaneh, Oppert et al. 2005). However, there were no consistencies in results observed according to the reliability or validity of the measures used. The studies that observed an inverse association between physical activity and measures of adiposity were generally shorter in duration (both 1 year), while the studies that observed no association tended to be longer in duration (2-10 years). Most of these studies had good follow-up ascertainment, ranging from 37.6% in one smaller study (Maffeis, Talamini et al. 1998) to approximately 90% in some of the larger studies (Berkey, Rockett et al. 2000; Kimm, Barton et al. 2001; Gordon-Larsen, Adair et al. 2002; Berkey, Rockett et al. 2003).

Results from prospective studies using self-reported measures of physical inactivity, such as television viewing or video game usage, are similarly inconsistent. Three studies observed a positive association between sedentary behaviours and adiposity measures in both boys and girls (Berkey, Rockett et al. 2000; Gordon-Larsen, Adair et al. 2002; Kaur, Choi et al. 2003), while one study observed the same association in girls only (Berkey, Rockett et al. 2003). Four studies observed no association in both boys and girls (Robinson, Hammer et al. 1993; Maffeis, Talamini et al. 1998; Bogaert, Steinbeck et al. 2003; Kettaneh, Oppert et al. 2005), while two studies observed no association in boys (Beunen, Malina et al. 1992; O'Loughlin, Gray-Donald et al. 2000; Berkey, Rockett et al. 2003). One study observed inconsistent findings in both boys and girls (Elgar, Roberts et al. 2005), while another observed inconsistencies among girls (O'Loughlin, Gray-Donald et al. 2000). None of the studies used validated or reliability tested measures to examine sedentary behaviours.

A summary of cross-sectional studies that have used objective measures of physical activity is presented in Appendix 13a (Table 3). Using pedometers to measure physical activity, Vincent and colleagues saw no association between physical activity and BMI (Vincent, Pangrazi et al. 2003). Similarly, there was no correlation between four days of pedometer readings and BMI in 892 Swedish children (Raustorp, Pangrazi et al. 2004). In a study of children in the UK using 7 days worth of accelerometer readings, obese children were significantly less active and spent less time in moderate and vigorous physical activity than non-obese children (Page, Cooper et al. 2005). In Portuguese children, mean physical activity counts and minutes of moderate to vigorous physical activity (derived from 3-days worth of accelerometer recordings) were higher in healthy weight girls than overweight girls, but no difference was noted in boys (Mota, Santos et al. 2002). Similarly, Treuth and colleagues observed a positive association between sedentary behaviours and adiposity, and an inverse association between light physical activity (but not moderate or vigorous physical activity) in girls, but not boys (Treuth, Hou et al. 2005). Using accelerometry, Abbott and colleagues observed an inverse association between vigorous and hard, but not moderate, physical activity and percent body fat (Abbott and Davies 2004). A Welsh study, however, observed no association between physical activity, measured by pedometers or accelerometers, and adiposity outcomes (Rowlands, Eston et al. 1999).

Studies that have used the doubly-labeled water (DLW) technique have shown equivocal results. Two studies (Abbott and Davies 2004; Rennie, Livingstone et al. 2005) observed inverse associations between physical activity measured by DLW and measures of adiposity, while another two other observed this same association in boys, but not girls (Ball, O'Connor et al. 2001; Rush, Plank et al. 2003). A German study (Grund, Vollbrecht et al. 2000) that used indirect calorimetry and heart rate monitoring to estimate total EE found a positive association with fat free mass.

Results from the 17 published cross-sectional reports of 13 studies assessing self-reported physical activity and adiposity are inconsistent, so inferences are difficult to make (Appendix 13a, Table 4). In boys, eight papers reported a negative association between physical activity and adiposity (Tell and Vellar 1988; Guillaume, Lapidus et al. 1997; Raitakari, Taimela et al. 1997; Schmidt, Stensel et al. 1997; McMurray, Harrell et al. 2000; Eisenmann, Bartee et al. 2002; Janssen, Katzmarzyk et al. 2004; Janssen, Katzmarzyk et al. 2005), while seven reported no association (Boreham, Twisk et al. 1997; Crespo, Smit et al. 2001; Deforche, Lefevre et al. 2003) or inconclusive results (Andersen, Crespo et al. 1998; Schmidt, Walkuski et al. 1998; Dowda, Ainsworth et al. 2001; Levin, Lowry et al. 2003). In girls, five of the published reports found a negative association between physical activity and adiposity (Boreham, Twisk et al. 1997; Schmidt, Stensel et al. 1997; Schmidt, Walkuski et al. 1998; Janssen, Katzmarzyk et al. 2004; Janssen, Katzmarzyk et al. 2005), while ten reported no association (Tell and Vellar 1988; Guillaume, Lapidus et al. 1997; Andersen, Crespo et al. 1998; McMurray, Harrell et al. 2000; Crespo, Smit et al. 2001; Eisenmann, Bartee et al. 2002; Deforche, Lefevre et al. 2003) or inconclusive results (Raitakari, Taimela et al. 1997; Dowda, Ainsworth et al. 2001; Levin, Lowry et al. 2003). A small number of studies used reliable measures of physical activity (Raitakari, Taimela et al. 1997; McMurray, Harrell et al. 2000; Eisenmann, Bartee et al. 2002; Levin, Lowry et al. 2003; Janssen, Katzmarzyk et al. 2004; Janssen, Katzmarzyk et al. 2005), but none employed well-validated measures. However, whether measures were reliable or valid appeared to have no influence on the findings, with negative, null and inconclusive results seen in all studies, regardless of the reliability or validity of measures.

The results from studies of the association between sedentary behaviours and adiposity provide stronger support for an association between physical inactivity and adiposity. Of the 11 published reports evaluated, six reported a positive association between television viewing and adiposity in both boys and girls (Gortmaker, Must et al. 1996; Andersen, Crespo et al. 1998; Crespo, Smit et al. 2001; Eisenmann, Bartee et al. 2002; Janssen, Katzmarzyk et al. 2004; Janssen, Katzmarzyk et al. 2005), while one study each reported a positive association between television viewing and adiposity in boys (Guillaume, Lapidus et al. 1997) and girls (Dowda, Ainsworth et al. 2001). Four studies reported no association in boys (Schmidt, Walkuski et al. 1998; McMurray, Harrell et al. 2000; Dowda, Ainsworth et al. 2001), while four reported no association in girls (Guillaume, Lapidus et al. 1997; Schmidt, Stensel et al. 1997; McMurray, Harrell et al. 2000). One study reported inconclusive results in both boys and girls (Wake, Hesketh et al. 2003). The finding that television viewing appears more strongly related to adiposity than physical activity supports the notion that television viewing may be easier and more accurately measured. It is possible that television viewing may be more structured, more regular and less spontaneous in nature than physical activity, and therefore more easily recalled.

The findings from intervention and observational studies, both prospective and cross-sectional, suggest, counter-intuitively, that the relationship between physical activity and measures of adiposity are weak at best. While limited in number, those that employed objective measures of physical activity generally found no association or had inconclusive results. Additionally, studies of this nature tended to have small sample sizes and focused on younger children. The findings from this literature review are in contrast to those reported by Must and Tybor (2005) who concluded that the available longitudinal evidence suggested that increased physical activity is protective against relative weight and fatness gains over childhood and adolescence. However, when studies reported in this review are restricted to participants of a similar age to that in the current study, the findings are not so clear. In general, studies that used objective measures of physical activity tended to be in younger children, where inverse relations were often found. Only one included study used pedometers to objectively measure physical activity in older children, with no significant findings, and one study used parental report with similar results. Of the five studies that used self-reported measures of physical activity in older children, mixed findings were observed.

It is difficult to explain the contrasting findings observed in studies of children's adiposity and physical activity. Some authors have suggested that self-reported measures of physical activity used are unlikely to be as accurate as objective measures, but studies using self-reported measures tend to observe stronger associations with adiposity. Studies of younger children tend to observe inverse associations, while studies in older children tend to observe more inconsistent findings. It is possible that changes in body composition associated with growth and maturation mask the association with physical activity in children of this age group. Alternatively, it is possible that a lack of heterogeneity in overall energy expenditure and adiposity levels of children and adolescents mean that small differences are difficult to detect.

3.2.2 Physical Activity & Cardiorespiratory Fitness in Children

There is currently no clear consensus about the relationship between physical activity and cardiorespiratory fitness in children. Evidence from laboratory studies suggest that children have high levels of cardiorespiratory fitness, despite large variability in physical activity and despite reports that many children are not participating in vigorous intensity physical activity (Pate, Long et al. 1994). Cardiorespiratory fitness levels tend to remain relatively stable throughout childhood and adolescence (regardless of the fitness measure), even though well-documented declines in physical activity occur (Telama and Yang 2000; van Mechelen, Twisk et al. 2000). While these points suggest that physical activity and cardiorespiratory fitness are unrelated in children, evidence from controlled training studies demonstrate that increases in physical activity can result in increased cardiorespiratory fitness (Baquet, van Praagh et al. 2003). In addition, children in the highest categories of physical activity are also often the fittest (Kemper and van Mechelen 1995).

A meta-analysis of the association between physical activity and cardiorespiratory fitness in children and adolescents showed only modest evidence for a relationship between physical activity and cardiorespiratory fitness (Trost 1998). The pooled correlation coefficient from 15 studies yielding 28 correlation coefficients was 0.17, a weak but significant association. Pooled correlation coefficients were also calculated according to sex (male/female), age (younger children/older children), measure of physical activity (objective/self-report) and measure of cardiorespiratory fitness (laboratory or quasi laboratory/field test). Correlation coefficients were marginally higher for girls (r=0.18 from 8 studies, n=1,391) than boys (r=0.13 from 12 studies, n=1,544) and there was no difference between younger children (r=0.16 from 12 studies, n=3,761) and older children (r=0.16 from 15 studies, n=2,493). Interestingly, studies that used self-reported measures of physical activity combined with a field test of cardiorespiratory fitness (n=4,177 from 7 studies) had higher correlation coefficients (r=0.18) than studies that used objective measures of physical activity (n=751 from 9 studies) or self-reported measures (n=1,283 from 9 studies) combined with laboratory or quasi laboratory measures of cardiorespiratory fitness, although the differences were marginal (r=0.14 and r=0.11, respectively). When the author analysed laboratory (n=294 from 5 studies) and quasi laboratory (n=989 from 4 studies) measures of cardiorespiratory fitness separately, little difference between laboratory (VO_2max) and quasi laboratory (PWC_{170}) measures of cardiorespiratory fitness in relation to objective measures of physical activity (r=0.15 and r=0.14, respectively) was found. When comparing laboratory and quasi laboratory measures in relation to self-reported physical activity, laboratory measures of cardiorespiratory fitness (n=74 from 3 studies) correlated more strongly (r=0.22, NS) with physical activity than quasi laboratory (n=677 from 6 studies) measures (r=0.10). However, only three studies that examined cardiorespiratory fitness using laboratory measures and physical activity using self-report, resulting in a small sample size (n=74) and therefore these findings must be interpreted with caution.

All these factors combined suggest that physical activity and cardiorespiratory fitness are weakly associated in children, and that mechanisms other than physical activity, such as genetics, may be more important in the development of cardiorespiratory fitness at this stage of life.

3.2.3 Cardiorespiratory Fitness & Adiposity in Children

While there appears to be a weak relationship between physical activity and weight status in children, the association between cardiorespiratory fitness and weight status appears stronger. This relationship is apparent irrespective of whether the measure of cardiorespiratory fitness was weight supported (i.e. cycle ergometer test) or weight-bearing (i.e. endurance run or sprint). A large study of 11,845 schoolchildren aged 5-13 years found that the mean number of fitness tests passed was lowest among students whose BMI was above the 80th percentile (Kim, Must et al. 2005). One year later, 6,297 of these children were reassessed. Findings suggested that failing the endurance run or upper body strength test was associated with overweight incidence in both boys and girls, and after adjusting for baseline BMI, low endurance run time remained a significant predictor of incident overweight in girls (OR: 2.0, 95% CI: 1.1-3.5). In addition, girls that failed one of the five fitness tests had 3.3 (95% CI: 2.0-5.6) times the odds of incident overweight compared with girls that failed none of the five fitness tests.

Another large study examined the association between adiposity (estimated from the sum of five skinfolds) and physical fitness (estimated from the PWC_{170} cycle test and step test) in 6,700 Belgian girls aged 7-17 years (Malina, Beunen et al. 1995). Results suggested that the fattest girls had the poorest levels of endurance fitness compared with the leanest girls. Similarly, a study of 3,214 Belgian adolescents aged 12-18 years found non-obese participants had better average values for both the speed shuttle run and endurance shuttle run tests than obese participants (Deforche, Lefevre et al. 2003). The differences in speed shuttle run times were greater in younger participants than older participants, and the differences in endurance shuttle run times between obese and non-obese children were greater in boys than girls.

Analysis of data from the ASHFS 1985 found age- and sex-adjusted correlation coefficients of -0.09 and -0.15 between BMI and the sum of four skinfolds, respectively, with a PWC_{170} cycle ergometer test (adjusted for lean body mass) (Dwyer and Gibbons 1994). However, when stratified by age and sex, only significant differences in BMI between fitness categories for boys and girls at age 9 and for boys aged 12 years existed. While trends were observed at other ages, these differences were not significantly different.

A two-year prospective study of 323 Greek children aged 6-12 years at baseline measured fitness using a 20m endurance shuttle run test and obesity using BMI and waist circumference (Psarra, Nassis et al. 2005). At follow-up, unfit children had 3.5 (95% CI: 1.6-7.5) times the odds of remaining in the top quartile of BMI, and 4.3 (95% CI: 1.5-12.0) times the odds of remaining in the top quartile for waist circumference than fit children. A cross-sectional report of the same study (n=1,362) observed lower skinfold thicknesses, BMI and percent body fat in fit children compared with unfit children, in both non-overweight and overweight children (Nassis, Psarra et al. 2005).

The findings from these studies suggest that irrespective of the measure of cardiorespiratory fitness, there appears to be a relationship between fitness and measures of adiposity in children that is stronger than the relationship between physical activity and adiposity. There is still some debate over whether the cardiorespiratory fitness-adiposity relationship in children is more apparent than the physical activity-adiposity relationship because fitness is more easily and accurately measured than physical activity, or whether the biological pathways through which physical activity and fitness influence adiposity differ. Most authors agree that it is the former, which seems more likely. Prospective studies that include objective measures of physical activity, cardiorespiratory fitness and overweight and obesity are likely to provide data that may assist in disentangling this, and other, issues.

3.3 Aims & Research Questions

While many studies have examined the relationship between physical activity and adiposity in children, no published reports have used a large, population-based sample of Australian children. In addition, few have also had the ability to examine the association between cardiorespiratory fitness and weight status in the same sample. Based on findings from the literature review, the aim of this chapter was to examine the cross-sectional relationship between weight status, physical activity and cardiorespiratory fitness in a population-based sample of Australian children aged 9-15 years. The specific research questions were:

1. Are physically active children more likely to be a healthy weight than less active children?
2. Are fitter children more likely to be a healthy weight than less fit children?

3.4 Methods

The methodology employed in the ASHFS 1985 has been described in detail in Chapter 2. A brief description of the participants, measures and statistical analyses relevant to the current chapter are provided here.

3.4.1 Participants

The subjects for this chapter were 8,498 children aged 7-15 years who participated in the ASHFS 1985. These children were randomly selected from 109 randomly selected government, Catholic and independent schools across Australia. In the first stage of sampling, schools were selected with a probability proportional to size, with a response rate of 90.1%. Children were then selected using simple random sampling to select 10 children from each age and sex group within each school, with a response rate of 67.5%. Those children aged 9-15 years completed a survey under the supervision of trained data collectors in groups of four (n=6,559). They also participated in a number of other tests (detailed below) and are therefore the focus of this study.

3.4.2 Measures

Briefly, 6,559 children aged 9-15 years had their height, weight and waist circumference measured. As described in Chapter 2 (section 2.1.5.3), all 9-15 year old children completed a questionnaire under supervision that asked about the frequency, duration and intensity of past week physical activity (the sum of school sport, school physical education, active commuting and non-organised activities); the number of extracurricular sports participated in during the past year (0-6); and the intensity of usual physical activity at recess and lunchtime at school (low, low-moderate, moderate-high, high). An investigation of "missing" values within the dataset resulted in exclusion of 145 questionnaires that were deemed incomplete (more than 25 out of 44 missing values) and provided support for treating "missing" values as non-participation in the physical activities listed (Appendix 13b, Tables 5, 6, 7, 8, 9 and 10). As an estimate of cardiorespiratory fitness, those children aged 9, 12 and 15 years completed a PWC_{170} cycle ergometer test (n=2,595). A subsample of those aged 9, 12 and 15 years also completed a maximal oxygen uptake (VO_2max) treadmill test (n=277).

3.4.3 Statistical Methods

Descriptive statistics (proportions, means and standard deviations for normally distributed data, or medians and inter-quartile ranges for non-normally distributed data) were used to characterise adiposity, physical activity and cardiorespiratory fitness levels of the sample. Chi-squared tests were used to determine whether sex differences in physical activity participation rates exist. To compare average adiposity, physical activity and cardiorespiratory fitness values between boys and girls, two-sample (unpaired) t-tests and one-way analysis of variance (ANOVA) were used where equal variance existed. Where variances were unequal, Kruskal-Wallis tests were used. Spearman correlation coefficients were calculated to compare the various measures of adiposity, physical activity and cardiorespiratory fitness. In addition, the relationship between physical activity and cardiorespiratory fitness was explored. Where physical activity variables were continuous, correlation coefficients were calculated. Where physical activity variables were categorical, mean or median cardiorespiratory fitness values were compared across categories using one-way ANOVA or the Kruskal-Wallis equality of populations rank test.

In bivariable analyses of categorical variables, a log binomial model was used to determine whether physically active children had a higher prevalence of healthy weight than physically inactive children. A log binomial model was also used to determine whether childhood sociodemographic factors were associated with being a healthy weight. Sociodemographic factors found to be significant in bivariable analyses were entered into a multivariable model to determine the effect on the relationship between physical activity and healthy weight. Age-adjusted prevalence ratios are reported throughout, with additional adjustments for sociodemographic factors as necessary. The same analyses were conducted to examine whether fit children had a higher prevalence of healthy weight than unfit children.

3.5 Characteristics of the Sample

An indicator of area-level SES is the index of relative socioeconomic disadvantage (IRSD), derived from the socioeconomic index for areas (SEIFA) and developed by the ABS (McLennan 1998) (see Chapter 2 for more detail). The SEIFA is determined using residential postcode and is based on questions asked in the population census. It takes into account different aspects of SES such as occupation and income. Table 11 shows the number and proportion of children falling into each of four SEIFA categories (low, low-medium, medium-high and high).

The largest proportion of children were from medium-low SES areas, while the smallest proportion were from low SES areas. Most children attended government (public) schools and approximately half indicated having never smoked and having two non-smoking parents. More than one third indicated that neither of their parents regularly exercised, while the large majority of children were born in Australia and spoke English at home.

Table 11: Sociodemographic characteristics of children in the ASHFS 1985, by sex

Sociodemographic Characteristic	**Boys**		**Girls**	
	n	**%**	**n**	**%**
SES				
Low	310	9.7	272	8.8
Medium-low	1,230	38.5	1,197	38.6
Medium-high	914	28.6	886	28.6
High	742	23.2	748	24.1
School Type				
Government	2,473	74.0	2,374	73.8
Catholic	669	20.0	695	21.6
Independent	200	6.0	140	4.6
Smoking				
>10 cigarettes	461	14.2	411	13.3
<10 cigarettes	250	7.7	212	6.9
A few puffs	828	25.5	658	21.3
Never smoked	1,707	52.6	1,814	58.6
Parental Smoking				
Neither smoke	1,612	49.9	1,606	51.1
Both smoke	534	16.5	512	16.3
Mother smokes	366	11.3	409	13.0
Father smokes	720	22.3	614	19.5
Parental PA				
Both parents active	553	18.4	630	21.5
Mother only active	518	17.3	537	18.3
Father only active	627	20.9	565	19.3
Both parents inactive	1,303	43.4	1,196	40.9
Country of Birth				
Australia	2,996	92.5	2,880	91.4
Outside Australia	244	7.5	270	8.6
Language at Home				
English	2,826	89.1	2,749	87.2
Non-English	418	12.9	403	12.8

3.6 The Outcome Measure: Adiposity

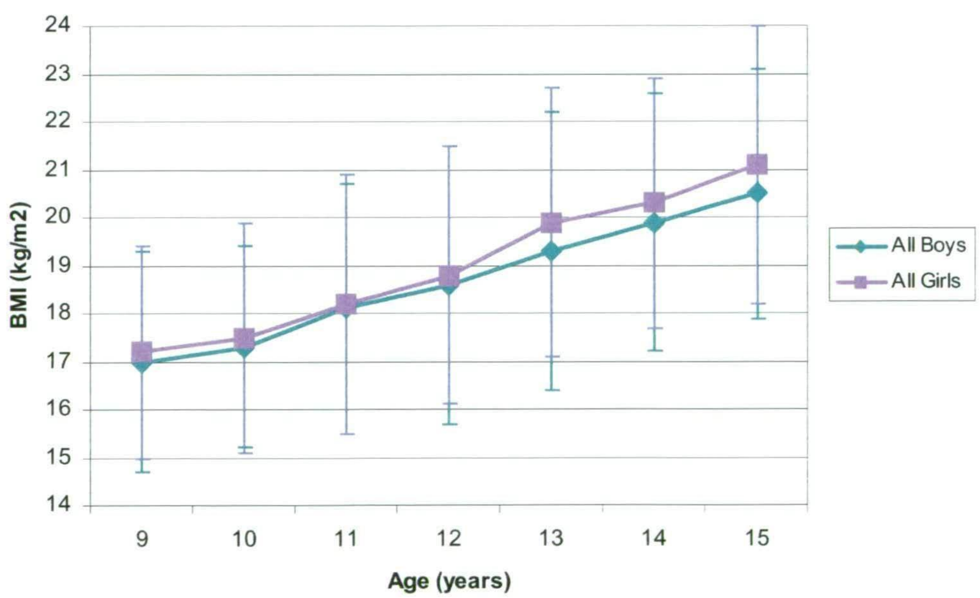
This section presents a description of the adiposity levels of children aged 9-15 years in the ASHFS 1985. A comparison of the measures of adiposity is included to gain an understanding of how the measures are related to each other. The prevalence of healthy weight, overweight and obesity in this sample is also presented.

3.6.1 Measures of Adiposity

As expected, weight increased with age in both sexes (*p* for trend, <0.01), with boys weighing more on average at ages 12, 14 and 15 years, although the differences were minimal in absolute terms. Average height increased with age (*p* for trend, <0.01). Boys were significantly taller than girls on average at ages 13-15 years ($p<0.01$), while girls were significantly taller at ages 11 and 12 years ($p=<0.01$ and $p<0.01$, respectively). Again, absolute differences were small and statistical differences are likely due to the large sample size (Appendix 13c, Table 11).

BMI has been recognised internationally as a useful tool for determining overweight and obesity in children, as previously discussed. Average BMI increased with age in both sexes (*p* for trend, $p<0.01$), and boys had significantly higher BMI values at ages 13-15 years ($p<0.01$, $p<0.05$, $p<0.01$, respectively) (Figure 14). See Appendix 13c, Table 12 for values. Again, differences were marginal in absolute terms.

Figure 14: Average BMI (kg/m^2) of boys and girls aged 9-15 years in the ASHFS 1985



Average waist circumference increased with age (*p* for trend, $p<0.01$ in both sexes), and on average, boys had larger waist circumferences at every age than girls (Appendix 13c, Table 13).

3.6.2 Comparison of Measures of Adiposity

To compare measures of adiposity, correlation coefficients between BMI and waist circumference were calculated (Table 12). Waist circumference was highly correlated with BMI in both boys and girls, suggesting that BMI is a reasonable estimate of fatness in this sample. Accepted cutpoints for overweight and obesity based on waist circumference have not been well established in children, and these adiposity measures were only available for a subsample of children. Additionally, BMI is an internationally accepted measure of adiposity with cutpoints for overweight and obesity specific to each age and sex group. While the limitations of BMI have been acknowledged (Cole, Bellizzi et al. 2000), the National Health and Medical Research Council of Australia recommends BMI for usage in population-based research (National Health and Medical Research Council 2003). For these reasons, BMI was used as the predominant measure of adiposity and overweight and obesity in this and further chapters.

Table 12: Spearman correlation coefficients for the association between BMI & waist circumference in children aged 9-15 years in the ASHFS1985, by sex

Age (years)	**Males**		**Females**	
	n	***r***	**n**	***r***
9	482	0.74**	487	0.75**
10	492	0.80**	497	0.79**
11	486	0.87**	484	0.80**
12	494	0.90**	489	0.80**
13	466	0.84**	437	0.75**
14	467	0.78**	406	0.70**
15	450	0.73**	412	0.75**
Overall	3,337	0.85**	3,212	0.81**

**p<0.01 *p<0.05

3.6.3 Prevalence of Healthy Weight, Overweight & Obesity

To determine the prevalence of healthy weight, overweight and obesity in children in the ASHFS 1985, the internationally accepted age- and sex-specific cutpoints defined by the (IOTF) (Cole, Bellizzi et al. 2000) were applied. These cutpoints are described in Chapter 2. Table 13 shows the number and proportion of children who were healthy weight, overweight and obese in 9-15 year olds in the ASHFS 1985. The majority of children in this sample were healthy weight, approximately 10% were overweight and 1.6% were obese.

Table 13: Number & proportion of children who were healthy weight, overweight or obese in the ASHFS 1985[a], by sex & age

Age	Sex	Healthy Weight[b]		Overweight		Obese	
		n	%	n	%	n	%
9	M	426	88.4	50	10.4	6	1.2
	F	416	85.3	65	13.3	7	1.4
10	M	447	90.7	42	8.5	4	0.8
	F	442	88.9	46	9.3	9	1.8
11	M	426	87.1	52	10.6	11	2.3
	F	418	86.4	58	12.0	8	1.7
12	M	437	88.5	43	8.7	14	2.8
	F	440	90.0	39	8.0	10	2.0
13	M	414	88.8	40	8.6	12	2.6
	F	381	87.0	52	11.9	5	1.1
14	M	422	90.4	40	8.6	5	1.1
	F	364	89.2	41	10.1	3	0.7
15	M	407	90.2	39	8.7	5	1.1
	F	359	86.9	49	11.9	5	1.2
Overall	M	2,979	89.1	306	9.2	57	1.7
	F	3,217	87.7	350	10.9	47	1.5

[a] Overweight and obesity defined according to internationally accepted age- and sex-specific cutpoints (Cole, Bellizzi et al. 2000)
[b] Healthy weight may include underweight

3.7 The Study Factors: Physical Activity & Cardiorespiratory Fitness

This section provides a description of the physical activity characteristics of the children involved in the ASHFS 1985. Firstly, the number and proportion of girls and boys by age who participated in extracurricular sport in the past year is presented, as well as the number of extracurricular sports played in the previous 12 months. The proportion of children reporting participation in school sport, school PE, active commuting, non-organised physical activity and total past week physical activity is presented, as is the average duration of past week physical activities. Finally, a description of children's discretionary physical activity at school during recess and lunchtime by sex and age is provided. Average values achieved for cardiorespiratory fitness - the PWC_{170} cycle ergometer test and maximal oxygen uptake – are described, and correlations between these measures are presented. Finally, the relationship between physical activity and cardiorespiratory fitness in children is explored.

3.7.1 Extracurricular Sport in the Past Year

The majority of boys and girls participated in at least one extracurricular sport in the previous 12 months (Table 14). Overall, a significantly higher proportion of boys participated in extracurricular sport in the past year than girls, but no significant differences in participation rates were seen between boys and girls when stratified by age. The average number of sports participated in during the past year for each age and sex is also presented. At most ages, boys participated in a greater number of extracurricular sports in the previous year than girls, although these differences were marginal. The average number of sports increased until age 12 years in girls and approximately age 13 years in boys, and then declined.

Table 14: Number & proportion of children participating in extracurricular sports in the past year in the ASHFS 1985, & the mean (standard deviation) number of extracurricular sports played, by sex & age

Age	Proportion Participating				p[a]	Number of Sports Played		p[b]
	Boys		Girls			Boys	Girls	
	n	%	n	%		Mean (SD)	Mean (SD)	
9	429	90.1	433	89.8	0.89	2.29 (1.50)	2.06 (1.35)	<0.05
10	454	94.8	458	93.7	0.46	2.64 (1.50)	2.32 (1.49)	<0.01
11	458	96.8	450	94.7	0.11	2.75 (1.50)	2.63 (1.52)	0.22
12	451	95.4	452	94.4	0.49	2.66 (1.41)	2.67 (1.52)	0.93
13	432	95.2	395	92.7	0.13	2.75 (1.56)	2.53 (1.54)	<0.05
14	433	95.6	371	92.8	0.08	2.68 (1.41)	2.44 (1.44)	<0.01
15	415	92.6	369	90.7	0.30	2.63 (1.46)	2.48 (1.52)	0.13
Overall	3,072	94.4	2,928	92.7	<0.01	2.63 (1.48)	2.44 (1.49)	<0.01

[a] p-values derived from Chi-squared test
[b] p-values derived from unpaired t-test

3.7.2 Past Week Physical Activity

The majority of children reported participating in some form of physical activity in the previous week (the sum of active commuting to or from school, school sport, school PE or non-organised physical activities outside school, as described in section 3.4.2) (Table 15). A higher proportion of primary school children participated in school sport and active commuting, while secondary school children reported greater participation in school PE. There was little difference by school level in the proportion of children participating in non-organised and total physical activity. In primary school, there was no difference in the median time reported by boys and girls for school sport, school PE or active commuting, but boys reported spending more time in non-organised physical activity and total physical activity than girls. At secondary school, boys reported more time in school sport, school PE (although median minutes were identical), non-organised physical activity and total physical activity, while girls reported significantly more time in active commuting.

Table 15: Children's past week self-reported school sport, school physical education, active commuting, non-organised physical activity & total physical activity in the ASHFS 1985, by sex & school level

School Level & Type of PA	Sex	Proportion doing this activity	Minutes spent in this activity		p[a]
		% (n/N)	Median	IQR	
Primary					
School Sport	M	67.4 (1,109/1,646)	60	(60, 120)	0.72
	F	66.2 (1,101/1,662)	60	(60, 120)	
School PE	M	71.1 (1,171/1,646)	60	(30, 75)	0.25
	F	71.2 (1,184/1,662)	60	(30, 90)	
Active Commuting	M	61.1 (1,006/1,646)	50	(30, 100)	0.53
	F	56.4 (938/1,662)	50	(30, 100)	
Non-organised PA	M	74.4 (1,225/1,646)	205	(100, 400)	<0.01
	F	73.6 (1,224/1,662)	140	(60, 300)	
Total PA [b]	M	99.1 (1,631/1,646)	304	(170, 530)	<0.01
	F	98.1 (1,631/1,662)	255	(150, 440)	
Secondary					
School Sport	M	51.8 (834/1,610)	105	(60, 170)	<0.01
	F	50.4 (754/1,496)	90	(60, 140)	
School PE	M	76.2 (1,227/1,610)	100	(80, 160)	<0.05
	F	73.7 (1,103/1,496)	100	(80, 150)	
Active Commuting	M	58.1 (936/1,610)	75	(46.5, 120.5)	<0.01
	F	50.9 (761/1,496)	100	(50, 150)	
Non-organised PA	M	78.2 (1,259/1,610)	270	(120, 525)	<0.01
	F	73.9 (1,106/1,496)	198	(90, 395)	
Total PA [b]	M	98.1 (1,579/1,610)	435	(250, 710)	<0.01
	F	97.8 (1,461/1,496)	345	(210, 570)	

[a] p-values derived from Kruskal-Wallis equality of populations rank test for differences between boys & girls
[b] Total PA is the sum of the other measures of physical activity (school sport, school PE, active commuting & non-organised physical activity)

3.7.3 Usual Recess & Lunchtime Physical Activity

Figures 15 and 16 show the proportion of boys and girls who participated in sedentary, moderate and vigorous activities at recess and lunchtime, and how these are categorised to form an estimate of overall activity during recess and lunchtime (low, low-moderate, moderate-high or high intensity). These categories are derived from combining self-reported intensity of usual physical activity at recess and with self-reported intensity of usual physical activity at lunchtime (detailed in Chapter 2). Approximately 50% of boys were vigorously active at both recess and lunchtime and were therefore deemed high active. Nearly 30% of girls reported being vigorously active at both recess and lunchtime, while 20% of girls reported moderate intensity activity at both recess and lunchtime, and just less than 15% were sedentary at both recess and lunchtime. There were significant differences in the proportion of boys and girls reporting participation in different intensity physical activities during recess and lunchtime. Boys reported greater participation in high intensity activities while girls reported greater participation in low, low-moderate and moderate-high intensity activities (p<0.01).

Figure 15: Proportion of boys aged 9-15 years who usually participate in low (aqua), low-moderate (mauve), moderate-high (gold) or high (maroon) intensity physical activity during recess and lunchtime in the ASHFS 1985

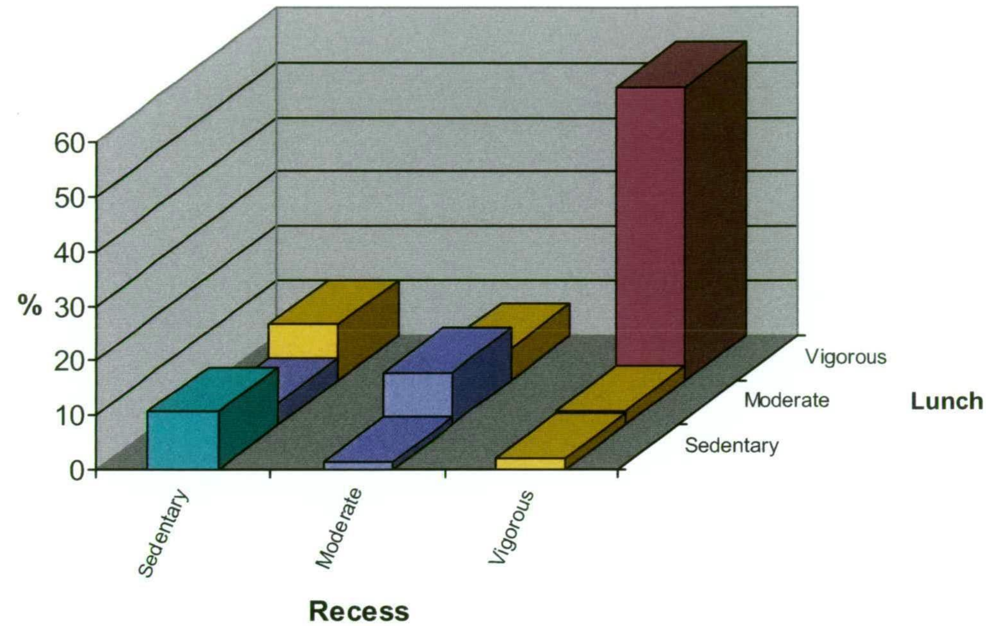
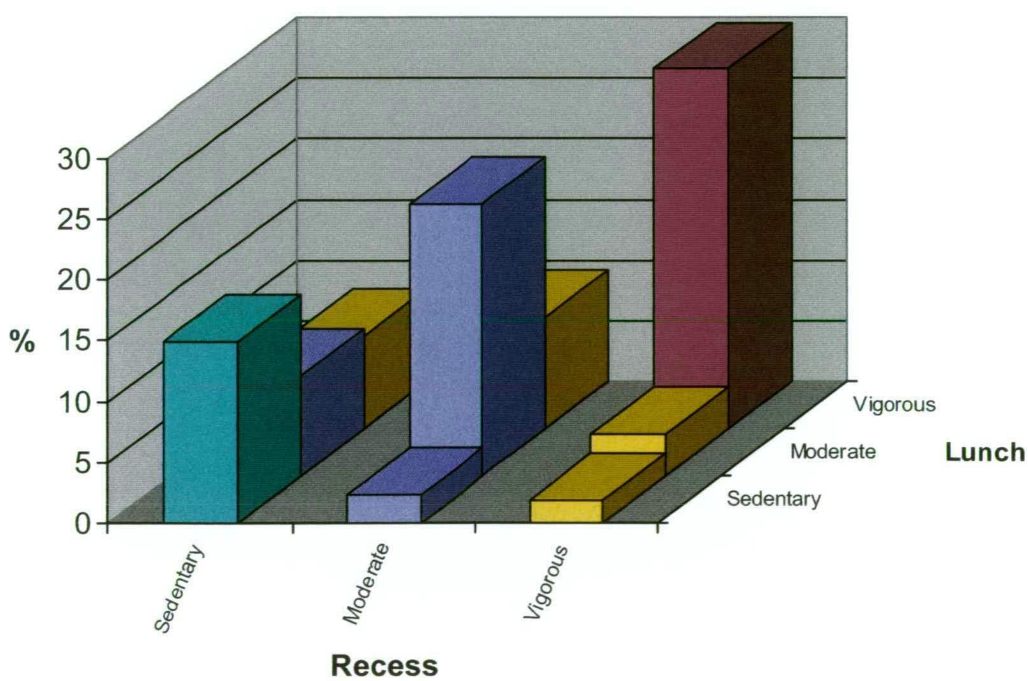


Figure 16: Proportion of girls aged 9-15 years who usually participate in low (aqua), low-moderate (mauve), moderate-high (gold) or high (maroon) intensity physical activity during recess and lunchtime in the ASHFS 1985



3.7.4 Cardiorespiratory Fitness

For the PWC_{170} test, boys had on average significantly higher values than girls overall and at each age, and boys' values increased with age, inferring greater cardiorespiratory fitness (Table 16). Girls' values increased until age 12 years then decreased at age 15 years. Average VO_2max ($ml.kg^{-1}.min^{-1}$) was higher in boys (Table 17).

Table 16: Average PWC_{170} (W/kglbm) for children aged 9, 12 & 15 years in the ASHFS 1985, by sex

Age (years)	Boys		Girls		p*
	n	Mean (SD)	n	Mean (SD)	
9	453	2.92 (0.66)	450	2.42 (0.57)	<0.01
12	448	2.95 (0.62)	449	2.58 (0.57)	<0.01
15	418	3.25 (0.72)	377	2.38 (0.72)	<0.01
Overall	1,319	3.03 (0.68)	1,276	2.46 (0.62)	<0.01

*p-value derived from unpaired t-test

Table 17: Average $VO2_{max}$ ($ml.kg^{-1}.min^{-1}$) for children aged 9, 12 & 15 years in the ASHFS 1985, by sex

Age (years)	Boys		Girls		p*
	n	Mean (SD)	n	Mean (SD)	
9	51	52.4 (7.0)	41	45.6 (5.5)	<0.01
12	52	51.5 (6.3)	51	45.8 (6.9)	<0.01
15	46	55.4 (6.5)	36	44.9 (5.9)	<0.01
Overall	149	53.0 (6.8)	128	45.5 (6.1)	<0.01

*p-value derived from unpaired t-test

3.7.5 Comparison of Cardiorespiratory Fitness Measures

The $VO2_{max}$ test was the most ideal (gold standard) measure of cardiorespiratory fitness used in the ASHFS 1985, but was only conducted on a small subsample of children (n=268). The PWC_{170} test is an objective test because workloads are administered using a standardised protocol and was completed by a large subsample of children (n=2,738). It is useful to compare the different measures of cardiorespiratory fitness to gain an understanding of their relationships to each other. The highest correlation coefficients between PWC_{170} and $VO2_{max}$ were observed in boys aged 12 years, while 12-year-old girls demonstrated the lowest correlation coefficients (Table 18). PWC_{170} and $VO2_{max}$ were significantly correlated at moderate levels in boys at all ages and in the youngest and oldest girls. While other studies have shown higher correlations between absolute measures of cardiorespiratory fitness (r=0.84) (Boreham, Paliczka et al. 1990), others have shown that associations are attenuated when relative measures adjusting for body weight are examined. For instance, Petzl and colleagues reported correlation coefficients of r=0.72 between absolute measures of PWC_{170} and $VO2_{max}$ (both estimated from a cycle ergometer test), which was reduced to 0.52 when body weight was taken into account in this both fitness measures (Petzl, Haber et al. 1988). It is likely that the lower correlations seen here are due to different modes of test administration; that is, PWC_{170} was estimated from a cycle ergometer test while $VO2_{max}$ was estimated from a treadmill test. It is also plausible that stage of maturation (which was not measured in this study) may have impacted on the relationship, potentially attenuating the association.

Table 18: Spearman correlation coefficients for the association between the PWC_{170} (W/kg) test & maximal oxygen uptake ($VO2_{max}$/kg) in children in the ASHFS 1985, by sex

Age (years)	Males		Females	
	N	*r*	n	*r*
9	49	0.40**	37	0.36*
12	50	0.44**	48	0.15
15	44	0.35*	33	0.41*

**p<0.01, *p<0.05

3.7.6 Physical Activity & Cardiorespiratory Fitness

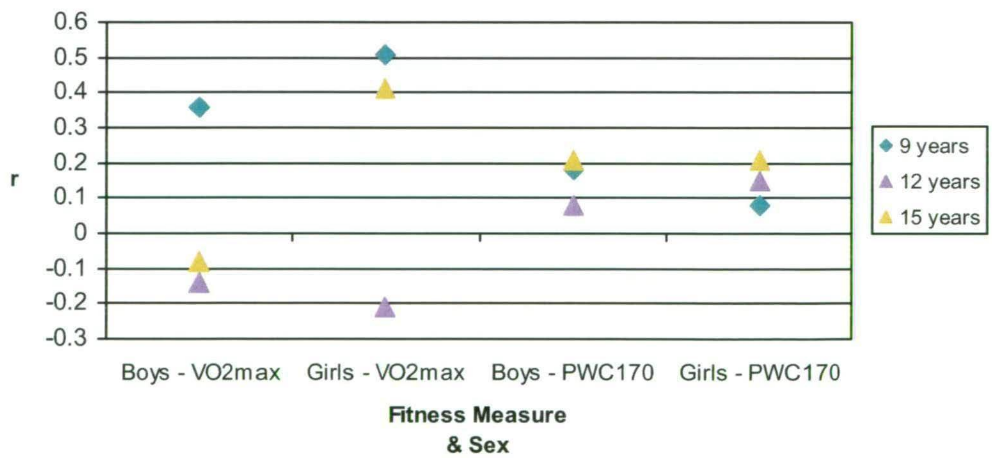
While objectively and subjectively measured physical activity and cardiorespiratory fitness have previously been shown to be correlated at low levels in childhood, the most physically active children are often also the fittest (Trost 2003). It is important to understand how the physical activity and cardiorespiratory fitness measures employed in this study relate to each other. These analyses aimed to examine the relationship between self-reported physical activity (number of extracurricular sports in the past year; minutes spent in past week physical activity; and intensity of recess and lunchtime physical activity) and cardiorespiratory fitness measures.

Associations between past year extracurricular sport and PWC_{170} and VO_2max were not strong (Figure 17). VO_2max was well correlated with past year extracurricular sport in 9-year-old boys, but weak correlations were seen for all other age and sex groups. PWC_{170} was significantly correlated with past year extracurricular sport at all ages tested except the youngest and oldest boys.

Figure 17: Summary correlations between self-reported past year extracurricular sport participation & cardiorespiratory fitness measures in children in the ASHFS 1985, by sex & age

All cardiorespiratory fitness measures were correlated with past week physical activity in the oldest girls and the youngest boys, but the associations were not as consistent for the other age groups (Table 18). Past week physical activity and $VO2_{max}$ were most strongly correlated in 9 year old girls.

Figure 18: Summary correlations between self-reported past week physical activity & cardiorespiratory fitness measures in children in the ASHFS 1985, by sex & age



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here was little difference in PWC_{170} values between children who participated in lower intensity physical activity at recess and lunchtime compared with children who participated in higher intensity physical activity (Appendix 13c, Table 14), with the exception of 15-year-old girls who had more favourable PWC_{170} scores with increasing level of recess and lunchtime activity. The association between recess and lunchtime physical activity and $VO2_{max}$ is not presented due to small cell sizes.

3.8 Sociodemographic Factors & Healthy Weight

In Table 19, relationships between healthy weight and sociodemographic factors are explored. For boys, increasing area-level SES was associated with a higher prevalence of healthy weight, while girls from the highest SES group had a higher prevalence of healthy weight. For boys, having an active mother was associated with a slightly elevated prevalence of healthy weight. In girls, having two active parents was associated with a small elevation in the prevalence of healthy weight, as was ever having a few puffs of a cigarette or having never smoked; no association was with smoking in boys. Speaking a language other than English at home was associated with a decreased prevalence of healthy weight in boys, but there was no difference in girls. School type, parental smoking and country of birth were not associated with healthy weight.

Table 19: Sociodemographic factors as predictors of healthy weight in children age 9-15 years in the ASHFS 1985, by sex

Sociodemo-graphic Factor	**Boys**				**Girls**			
	Healthy Weight		**PR[a]**	**(95% CI)**	**Healthy Weight**		**PR[a]**	**(95% CI)**
	%	**(n/N)**			**%**	**(n/N)**		
SES								
Low	81.0	(251/310)	1.0		82.7	(225/272)	1.0	
Low-medium	89.1	(1,096/1,230)	**1.10**	**(1.04-1.17)**	87.5	(1,047/1,197)	1.06	(1.00-1.12)
Medium-high	88.8	(812/914)	**1.10**	**(1.04-1.17)**	86.3	(765/886)	1.04	(0.98-1.11)
High	91.6	(680/742)	**1.13**	**(1.07-1.20)**	90.5	(677/748)	**1.10**	**(1.03-1.16)**
School Type								
Government	88.6	(2,192/2,473)	1.0		87.1	(2,067/2,374)	1.0	
Catholic	90.9	(608/669)	1.02	(1.00-1.05)	88.9	(618/695)	1.02	(0.99-1.05)
Independent	89.5	(179/200)	1.01	(0.96-1.06)	91.2	(135/148)	1.05	(0.99-1.10)
Parental PA								
Neither active	87.6	(1,142/1,303)	1.0		87.0	(1,040/1,196)	1.0	
Mum active only	91.5	(474/518)	**1.04**	**(1.01-1.08)**	88.5	(475/537)	1.02	(0.98-1.06)
Dad active only	90.8	(569/627)	1.04	(1.00-1.07)	85.3	(482/565)	0.98	(0.94-1.02)
Both active	88.4	(489/553)	1.01	(0.97-1.05)	90.3	(569/630)	1.04	(1.01-1.08)
Smoking								
>10 cigarettes	90.0	(415/461)	1.0		84.1	(348/414)	1.0	
<10 cigarettes	88.0	(220/250)	1.00	(0.96-1.04)	91.2	(197/216)	1.05	(1.00-1.10)
A few puffs	87.6	(725/828)	0.98	(0.94-1.02)	89.0	(593/666)	**1.07**	**(1.01-1.12)**
Never smoked	89.2	(1,523/1,707)	0.98	(0.93-1.04)	87.2	(1,616/1,853)	**1.09**	**(1.02-1.15)**
Parental Smoking								
Both smoke	88.2	(471/534)	1.0		85.7	(439/512)	1.0	
Mum only	87.2	(319/366)	0.99	(0.94-1.04)	83.6	(342/409)	0.98	(0.92-1.03)
Dad only	86.3	(621/720)	0.98	(0.94-1.02)	86.2	(529/614)	1.00	(0.96-1.05)
Neither smoke	90.6	(1,461/1,612)	1.03	(0.99-1.06)	89.4	(1,435/1,606)	1.04	(1.00-1.08)
Country of Birth								
Australia	88.9	(2,664/2,996)	1.0		87.7	(2,517/2,880)	1.0	
Not Australia	87.7	(214/244)	0.98	(0.94-1.03)	87.8	(237/270)	1.00	(0.96-1.05)
Language at Home								
English	90.3	(2,550/2,826)	1.0		87.6	(2,407/2,749)	1.0	
Non-English	78.7	(329/418)	**0.87**	**(0.83-0.91)**	85.6	(345/403)	0.98	(0.94-1.02)

[a] PR: prevalence ratios adjusted for age

3.9 Healthy Weight, Physical Activity & Cardiorespiratory Fitness

In this section, the association between healthy weight and physical activity is explored. In bivariable analyses, it was observed that SES, parental physical activity, smoking (girls only) and language spoken at home (boys only) were associated with healthy weight. In the following section, these variables were added to the model in order to determine whether they confounded the relationship between healthy weight and physical activity.

3.9.1 Healthy Weight & Participation in Physical Activity

There was no difference in the prevalence of healthy weight according to frequency of participation in physical activity in boys (Table 20) or girls (Table 21). The associations changed very little after adjustment for age, SES, parental physical activity and language spoken at home.

Table 20: Ratios of prevalence of healthy weight according to participation in physical activity for boys aged 9-15 years in the ASHFS 1985

Type & Frequency of PA	Healthy Weight %	(n/N)	PR[a]	(95% CI)	PR[b]	(95% CI)
Extracurricular sport						
0-1 sports	88.3	(756/856)	1.0		1.0	
2 sports	91.2	(803/881)	1.03	(1.00-1.07)	**1.05**	**(1.01-1.08)**
3 sports	87.8	(650/740)	0.99	(0.96-1.03)	1.02	(0.98-1.06)
4+ sports	89.0	(770/865)	1.01	(0.97-1.04)	1.03	(0.99-1.06)
School sport						
Never	89.4	(1,243/1,390)	1.0		1.0	
1/week	88.4	(1,143/1,293)	0.99	(0.96-1.02)	1.00	(0.98-1.03)
2/week	90.0	(298/331)	1.01	(0.97-1.05)	1.01	(0.98-1.05)
3+/week	89.9	(295/328)	1.00	(0.97-1.05)	1.02	(1.00-1.05)
Physical Education						
Never	90.2	(843/935)	1.0		1.0	
1/week	88.7	(826/931)	0.99	(0.96-1.02)	0.99	(0.96-1.03)
2/week	89.7	(797/889)	0.99	(0.96-1.03)	0.99	(0.97-1.03)
3+/week	87.4	(513/587)	0.97	(0.94-1.01)	0.98	(0.94-1.01)
Active Commuting						
Never	90.1	(1,254/1,392)	1.0		1.0	
1-4/week	88.4	(282/319)	0.98	(0.94-1.03)	0.98	(0.94-1.02)
5-9/week	88.0	(636/723)	0.98	(0.95-1.01)	1.00	(0.97-1.03)
10+/week	88.9	(807/908)	0.99	(0.96-1.02)	1.00	(1.00-1.00)
Non-organised PA						
Never	89.2	(775/869)	1.0		1.0	
1-4/week	89.7	(1,237/1,379)	1.01	(0.98-1.03)	1.01	(0.98-1.04)
5-9/week	87.7	(662/755)	0.98	(0.95-1.02)	0.99	(0.95-1.03)
10+/week	90.0	(305/339)	1.01	(0.97-1.05)	1.01	(0.96-1.05)

[a] PR: prevalence ratios adjusted for age
[b] PR: prevalence ratios adjusted for age, SES, parental physical activity & language spoken at home

Table 21: Ratios of prevalence of healthy weight according to participation in physical activity for girls aged 9-15 years in the ASHFS 1985

Type & Frequency of PA	Healthy Weight %	(n/N)	PR[a]	(95% CI)	PR[b]	(95% CI)
Extracurricular sport						
0-1 sports	87.6	(858/980)	1.0		1.0	
2 sports	87.5	(750/857)	1.00	(0.97-1.04)	1.01	(0.98-1.05)
3 sports	88.8	(584/658)	1.01	(0.98-1.05)	1.02	(0.98-1.05)
4+ sports	87.0	(628/722)	0.99	(0.96-1.03)	1.02	(0.98-1.06)
School sport						
Never	86.9	(1,164/1,339)	1.0		1.0	
1/week	88.1	(1,085/1,231)	1.02	(0.99-1.05)	1.02	(0.99-1.05)
2/week	89.8	(308/343)	1.03	(0.99-1.08)	1.03	(0.99-1.07)
3+/week	86.5	(263/304)	1.00	(0.95-1.05)	1.00	(0.95-1.05)
Physical Education						
Never	86.6	(798/922)	1.0		1.0	
1/week	87.3	(754/864)	1.01	(0.97-1.05)	1.02	(0.99-1.06)
2/week	87.7	(802/915)	1.01	(0.98-1.05)	1.02	(0.99-1.06)
3+/week	90.3	(466/516)	1.04	(1.00-1.08)	**1.06**	**(1.03-1.10)**
Active Commuting						
Never	87.7	(1,322/1,508)	1.0		1.0	
1-4/week	86.9	(253/291)	0.99	(0.95-1.04)	1.01	(0.97-1.06)
5-9/week	87.7	(572/652)	1.00	(0.97-1.04)	1.00	(0.97-1.04)
10+/week	87.9	(673/766)	1.00	(0.97-1.04)	1.02	(0.99-1.05)
Non-organised PA						
Never	86.8	(782/901)	1.0		1.0	
1-4/week	87.9	(1,269/1,444)	1.01	(0.98-1.05)	1.01	(0.98-1.04)
5-9/week	87.6	(532/607)	1.01	(0.97-1.05)	1.03	(0.99-1.07)
10+/week	89.4	(237/265)	1.03	(0.98-1.08)	1.03	(0.99-1.08)

[a] PR: prevalence ratios adjusted for age
[b] PR: prevalence ratios adjusted for age, SES, parental physical activity & smoking

3.9.2 Healthy Weight & Time Spent in Physical Activity

While there were few statistically significant differences between median self-reported physical activity of healthy weight and overweight children, discretional physical activity tended to be higher in healthy weight children (Table 22). In primary school children, median minutes of school sport, school physical education and active commuting were identical for healthy weight and overweight children, likely a reflection of the compulsory nature of physical education and school sport, but non-organised physical activity and total weekly physical activity tended to be higher in the healthy weight children. A similar trend was noted in secondary school females, but healthy weight secondary school males tended to report more activity in all domains than overweight boys, possibly a reflection of the non-compulsory nature of school physical education and school sport at secondary school.

Table 22: Past week physical activity (minutes) reported by healthy weight & overweight children aged 9-15 years in the ASHFS 1985, by sex & school level

School Level, Sex & Type of PA	Healthy Weight			Overweight		p[a]
	% (n/N)	Median (IQR)		Median (IQR)		
Primary School						
Boys						
Total PA[b]	88.7 (1,444/1,628)	305	(170, 527.5)	297.5	(164.5, 540)	0.70
School Sport	88.7 (983/1,108)	60	(60, 120)	60	(50, 120)	0.74
School PE	88.0 (1,028/1,168)	60	(30, 75)	60	(30, 90)	0.15
Active Commuting	80.0 (882/1,003)	50	(30, 100)	50	(25, 100)	0.56
Non-organised PA	88.9 (1,086/1,222)	210	(105, 400)	180	(73.5, 365)	0.16
Girls						
Total PA[b]	86.9 (1,418/1,631)	260	(150, 240)	230	(130, 392)	0.05
School Sport	87.6 (965/1,101)	60	(60, 120)	60	(47.5, 120)	0.16
School PE	87.2 (1,032/1,184)	60	(30/90)	60	(30/90)	0.58
Active Commuting	85.6 (803/938)	50	(30, 100)	50	(30, 100)	0.70
Non-organised PA	87.1 (1,066/1,224)	150	(60, 305)	120	(60, 255)	0.18
Secondary School						
Boys						
Total PA[b]	89.0 (1,404/1,578)	440	(255, 708.5)	385.5	(225, 730)	0.15
School Sport	89.1 (743/834)	106	(70, 180)	90	(60, 150)	<0.05
School PE	89.2 (1,095/1,227)	100	(80, 160)	90	(80, 135)	<0.01
Active Commuting	88.6 (813/918)	75	(48, 125)	75	(45, 100)	0.90
Non-organised PA	89.3 (1,123/1,258)	270	(120, 510)	250	(150, 560)	0.74
Girls						
Total PA[b]	88.0 (1,285/1,460)	350	(210, 580)	330	(180, 550)	0.15
School Sport	88.6 (668/754)	90	(60, 140)	90	(60, 120)	0.80
School PE	88.9 (980/1,102)	100	(80, 150)	100	(80, 150)	0.91
Active Commuting	89.6 (681/760)	100	(50, 150)	100	(50, 120)	0.44
Non-organised PA	88.6 (979/1,105)	185	(90, 390)	220	(120, 440)	0.74

[a] p-values derived from Kruskal-Wallis test
[b] Total PA is the sum of all other domains of physical activity (school sport, school PE, active commuting & non-organised physical activity)

A log binomial model was used to compare the prevalence of healthy weight according to frequency of participation in various physical activities. In general, increasing participation in extracurricular sport in the past year and past week participation in school sport, school PE, active commuting to or from school, non-organised physical activity and total weekly physical activity was not associated with an increase in the prevalence of healthy weight (Tables 23 and 24). Adjusting for SES, language spoken at home (boys only) and smoking (girls only) made no difference to the apparent lack of association between healthy weight and duration of children's self-reported physical activity. Girls who reported the highest amount of time in total past week physical activity had a slightly increased prevalence of healthy weight, compared with those who reported the least amount of activity.

Table 23: Ratios of prevalence of healthy weight for boys categorised by self-reported past week physical activity in the ASHFS 1985

Type & Duration of PA	Healthy Weight %	(n/N)	PR[a]	(95% CI)	PR[b]	(95% CI)
Total PA						
<3hr/wk	89.4	(681/762)	1.0		1.0	
3-6hr/wk	87.8	(839/956)	0.98	(0.95-1.01)	1.00	(0.96-1.03)
6-9hr/wk	90.5	(542/599)	1.01	(0.97-1.05)	1.03	(0.99-1.07)
9+hr/wk	89.5	(917/1,025)	1.00	(0.97-1.03)	1.00	(0.98-1.05)
School Sport						
<30m/wk	89.3	(1,304/1,460)	1.0		1.0	
30-59m/wk	86.8	(275/317)	0.97	(0.93-1.02)	0.99	(0.95-1.04)
60-89m/wk	88.1	(495/562)	0.99	(0.95-1.02)	1.00	(0.97-1.03)
90+m/wk	90.2	(905/1,003)	1.01	(0.98-1.04)	1.02	(0.99-1.04)
School PE						
<30m/wk	89.9	(928/1,032)	1.0		1.0	
30-59m/wk	88.5	(525/593)	0.99	(0.95-1.02)	1.00	(0.97-1.04)
60-89m/wk	88.4	(584/661)	0.98	(0.95-1.02)	0.99	(0.95-1.02)
90+m/wk	89.2	(942/1,056)	0.96	(0.96-1.02)	1.00	(0.97-1.03)
Commuting						
<30m/wk	89.4	(1,588/1,776)	1.0		1.0	
30-59m/wk	88.7	(511/576)	0.99	(0.96-1.03)	1.01	(0.97-1.04)
60-89m/wk	90.2	(221/245)	1.01	(0.96-1.05)	1.01	(0.97-1.06)
90+m/wk	88.5	(659/745)	0.99	(0.96-1.02)	1.01	(0.98-1.04)
Non-organised PA						
<60m/wk	89.0	(952/1,070)	1.0		1.0	
60-149m/wk	88.6	(513/579)	1.00	(0.96-1.03)	1.00	(0.97-1.04)
150-300m/wk	88.9	(570/641)	1.00	(0.96-1.03)	1.00	(0.97-1.04)
300+m/wk	89.7	(944/1,052)	1.01	(0.98-1.04)	1.02	(0.99-1.05)

[a] PR: prevalence ratios adjusted for age

[b] PR: prevalence ratios adjusted for age, SES & language spoken at home

Table 24: Ratios of prevalence of healthy weight for girls categorised by self-reported past week physical activity in the ASHFS 1985

Type & Duration of PA	Healthy Weight %	(n/N)	PR[a]	(95% CI)	PR[b]	(95% CI)
Total PA						
<3hr/wk	86.2	(796/924)	1.0		1.0	
3-6hr/wk	87.3	(903/1,034)	1.01	(0.98-1.05)	1.03	(0.99-1.07)
6-9hr/wk	88.8	(491/553)	1.03	(0.99-1.07)	1.04	(1.00-1.08)
9+hr/wk	89.2	(630/706)	1.03	(1.00-1.07)	**1.05**	**(1.01-1.09)**
School Sport						
<30m/wk	86.8	(1,240/1,429)	1.0		1.0	
30-59m/wk	86.9	(265/305)	1.00	(0.96-1.05)	1.01	(0.96-1.06)
60-89m/wk	88.1	(512/581)	1.01	(0.98-1.05)	1.03	(0.99-1.07)
90+m/wk	89.0	(803/902)	1.03	(0.99-1.01)	1.03	(1.00-1.06)
School PE						
<30m/wk	86.9	(882/1,015)	1.0		1.0	
30-59m/wk	86.5	(498/576)	1.00	(0.96-1.04)	1.00	(0.96-1.04)
60-89m/wk	89.3	(578/647)	1.03	(0.99-1.07)	1.03	(0.99-1.06)
90+m/wk	88.1	(862/979)	1.01	(0.98-1.05)	1.01	(0.98-1.05)
Commuting						
<30m/wk	87.7	(1,591/1,815)	1.0		1.0	
30-59m/wk	86.5	(404/467)	0.99	(0.95-1.03)	1.00	(0.96-1.04)
60-89m/wk	88.3	(203/230)	1.01	(0.96-1.06)	1.00	(0.95-1.05)
90+m/wk	88.2	(622/705)	1.01	(0.97-1.04)	1.01	(0.98-1.05)
Non-organised PA						
<60m/wk	87.5	(1,049/1,199)	1.0		1.0	
60-149m/wk	86.9	(650/748)	0.99	(0.96-1.03)	1.00	(0.96-1.03)
150-300m/wk	88.3	(485/549)	1.01	(0.97-1.05)	1.03	(0.99-1.06)
300+m/wk	88.2	(636/721)	1.01	(0.97-1.04)	1.02	(0.99-1.06)

[a] PR: prevalence ratios adjusted for age
[b] PR: prevalence ratios adjusted for age, SES & smoking

3.9.3 Healthy Weight & Usual Recess & Lunchtime Physical Activity

After adjusting for age, SES, language spoken at home (boys only) and smoking (girls only), there remained no association between healthy weight and children's self-reported intensity of recess and lunchtime physical activity (Table 25).

Table 25: Ratios of prevalence of healthy weight for children categorised by intensity of usual physical activity at recess/lunchtime in the ASHFS 1985, by sex

Sex & Intensity of Recess/ Lunch PA	Healthy Weight %	(n/N)	PR[a]	(95% CI)	PR[b]	(95% CI)
Boys						
Low	90.4	(309/342)	1.0		1.0	
Low-Mod	87.9	(421/479)	0.97	(0.93-1.02)	0.98	(0.94-1.03)
Mod-High	87.3	(592/678)	0.97	(0.93-1.02)	0.98	(0.94-1.02)
High	89.3	(1,547/1,732)	0.99	(0.95-1.03)	1.00	(0.97-1.04)
Girls						
Low	86.1	(404/469)	1.0		1.0	
Low-Mod	88.0	(917/1,042)	1.02	(0.98-1.07)	1.03	(0.99-1.07)
Mod-High	85.5	(603/705)	1.00	(0.95-1.05)	1.00	(0.95-1.05)
High	88.9	(829/933)	1.04	(0.99-1.09)	1.04	(1.00-1.09)

[a] PR: prevalence ratios adjusted for age
[b] PR: prevalence ratios adjusted for age, SES, language spoken at home (boys only) & smoking (girls only)

3.9.4 Healthy Weight & Cardiorespiratory Fitness

While healthy weight children generally had higher maximal oxygen uptake values, these differences were only significantly different for boys age 12 (Table 26). However, the small number of participants in each cell resulted in reduced statistical power to detect differences.

Table 26: Mean (standard deviation) VO2max ($ml.kg^{-1}.min^{-1}$) for healthy weight & overweight children in the ASHFS 1985, by sex & age

Age	Sex	Healthy Weight %	(n/N)	Healthy Weight (Mean, SD)		Overweight (Mean, SD)		p[a]
9	M	92.2	(47/51)	52.9	(7.0)	46.7	(5.0)	0.09
	F	87.8	(36/41)	46.1	(5.5)	42.1	(4.6)	0.12
12	M	90.4	(47/52)	52.5	(5.7)	42.8	(3.6)	<0.01
	F	94.1	(48/51)	46.1	(6.7)	39.6	(7.5)	0.11
15	M	91.3	(42/46)	55.4	(6.7)	55.4	(4.1)	0.98
	F	88.9	(32/36)	45.2	(6.1)	42.1	(2.4)	0.33

[a] p-values derived from one-way ANOVA

In general, healthy weight children had higher levels of cardiorespiratory fitness as measured by the PWC_{170} cycle ergometer test (Table 27), except for 9 and 15 year old girls. The magnitude of the differences noted was larger in boys than girls. Overall, the findings for PWC_{170} are consistent with the findings for $VO2_{max}$.

Table 27: Mean (standard deviation) PWC_{170}[a] (W/kglbm) for healthy weight & overweight children in the ASHFS 1985, by sex & age

Age	Sex	Healthy Weight		Healthy Weight		Overweight		p[b]
		%	(n/N)	(Mean, SD)		(Mean, SD)		
9	M	89.0	(403/453)	17.7	(4.1)	16.2	(4.1)	<0.05
	F	84.4	(380/450)	14.6	(3.5)	14.2	(3.0)	0.49
12	M	87.9	(394/448)	17.8	(3.6)	16.7	(4.1)	<0.05
	F	89.5	(402/449)	15.6	(3.2)	14.6	(4.7)	<0.05*
15	M	90.0	(376/418)	19.7	(5.6)	17.7	(5.6)	<0.05*
	F	87.8	(331/377)	14.4	(4.4)	13.4	(3.8)	0.07*

[a] PWC_{170} adjusted for lean body mass
[b] p-values derived from one-way ANOVA except for (*) derived from Kruskal-Wallis test

Boys aged 12 years in the highest third of cardiorespiratory fitness had a slightly elevated prevalence of healthy weight, compared with those in the lowest third (Table 28). However, there was no significant difference in the prevalence of healthy weight for boys aged 9 or 15 years. Adjusting for sociodemographic factors made little, if any, difference to the estimates.

Table 28: Ratios of prevalence of healthy weight categorised by thirds of cardiorespiratory fitness (PWC_{170}[a]) in Australian boys, by age

Age & Fitness Third	Healthy Weight		PR[b]	(95% CI)	Adj. PR[c]	(95% CI)
	%	(n/N)				
9 years						
Lowest Third	85.9	(128/149)	1.0		1.0	
Middle Third	90.1	(132/147)	1.05	(0.96-1.14)	1.04	(0.97-1.12)
Highest Third	91.1	(143/157)	1.06	(0.98-1.15)	1.03	(0.96-1.10)
				P_{trend} = 0.15		P_{trend} = 0.25
12 years						
Lowest Third	83.6	(127/152)	1.0		1.0	
Middle Third	87.7	(128/146)	1.05	(0.96-1.15)	1.07	(0.98-1.17)
Highest Third	92.7	(139/150)	**1.11**	**(1.02-1.21)**	**1.12**	**(1.03-1.22)**
				P_{trend} = 0.02		P_{trend} < 0.01
15 years						
Lowest Third	86.5	(122/141)	1.0		1.0	
Middle Third	89.7	(122/136)	1.04	(0.95-1.13)	1.01	(0.93-1.09)
Highest Third	93.6	(132/141)	1.08	(1.00-1.17)	1.06	(0.99-1.15)
				P_{trend} = 0.05		P_{trend} = 0.09

[a] PWC_{170} adjusted for lean body mass
[b] PR: unadjusted prevalence ratios
[c] Adj. PR: prevalence ratios adjusted for SES, language spoken at home, parental physical activity

Twelve-year-old girls in the middle third and 15 year-old girls in the highest third of cardiorespiratory fitness had a slightly elevated prevalence of healthy weight (Table 29). However, this association in 12-year old girls disappeared after adjusting for sociodemographic factors. There was no significant difference in the prevalence of healthy weight according to cardiorespiratory fitness third at any other age.

Table 29: Ratios of prevalence of healthy weight categorised by thirds of cardiorespiratory fitness (PWC_{170} [a]) in Australian girls, by age

Age & Fitness Third	**Healthy Weight %**	**(n/N)**	**PR[b]**	**(95% CI)**	**Adj. PR[c]**	**(95% CI)**
9 years						
Lowest Third	84.6	(126/149)	1.0		1.0	
Middle Third	79.3	(119/150)	0.94	(0.84-1.04)	0.96	(0.86-1.07)
Highest Third	88.1	(133/151)	1.04	(0.95-1.14)	1.03	(0.94-1.13)
				P_{trend} = 0.40		P_{trend} = 0.69
12 years						
Lowest Third	84.1	(122/145)	1.0		1.0	
Middle Third	93.4	(142/152)	**1.11**	**(1.02-1.21)**	1.06	(0.98-1.15)
Highest Third	90.8	(138/152)	1.08	(0.99-1.18)	1.02	(0.94-1.10)
				P_{trend} =0.07		P_{trend} =0.62
15 years						
Lowest Third	83.9	(104/124)	1.0		1.0	
Middle Third	88.5	(116/131)	1.06	(0.96-1.17)	1.06	(0.95-1.17)
Highest Third	91.0	(111/122)	1.08	(0.99-1.19)	**1.12**	**(1.02-1.23)**
				P_{trend} = 0.09		P_{trend} =0.01

[a] PWC_{170} adjusted for lean body mass
[b] PR: unadjusted prevalence ratio
[c] Adj. PR: prevalence ratios adjusted for SES, cigarette smoking & parental physical activity

3.10 Discussion

This chapter aimed to determine whether physically active or fit children had a higher prevalence of healthy weight than physically inactive or unfit children. The findings suggest that the prevalence of healthy weight was similar between physically active and less active children. Frequency of participation was not predictive of being a healthy weight. Overall, healthy weight children tended to report more time in discretionary physical activity at school than overweight children (non-significant), but values were similar between healthy weight and overweight children for school-based activities. However, the duration of self-reported physical activity was not associated with an increase in the prevalence of healthy weight. Similarly, the reported intensity of children's physical activity during their discretionary time at school did not vary according to weight status, and this type of physical activity was not associated with an increase in the prevalence of healthy weight.

While in general boys tended to report more physical activity than girls, there was little, if any, difference between boys and girls in the associations observed. In addition, adjustments for age, SES, smoking, parental physical activity and language spoken at home made very little, if any, difference to the findings. While higher SES and speaking a language other than English at home were the sociodemographic factors most strongly associated with healthy weight, particularly in boys, they made very little impact when added to the multivariable models, suggesting that these factors were not confounding the relationship between healthy weight and physical activity.

Although physical activity was not predictive of a healthy weight, healthy weight children showed more favourable cardiorespiratory fitness levels than overweight children. This finding has been observed in a number of other large, well-conducted studies (Dwyer and Gibbons 1994; Malina, Beunen et al. 1995; Deforche, Lefevre et al. 2003; Kim, Must et al. 2005; Psarra, Nassis et al. 2005). Due to the cross-sectional nature of this study, the temporal nature of the relationship observed between healthy weight and cardiorespiratory fitness cannot be determined. It is unknown if healthy weight children were more likely to participate in cardiorespiratory fitness-enhancing activities or whether participation in these activities helped to prevent overweight. In addition, the lack of variation in BMI may have made it difficult to detect differences in physical activity and cardiorespiratory fitness levels between healthy weight and overweight children.

The findings of this study may have a number of possible interpretations. First, it is possible that no association exists between physical activity and healthy weight in children. A number of other cross-sectional studies that have used self-reported measures of physical activity have observed similar findings (Tell and Vellar 1988; Boreham, Twisk et al. 1997; Guillaume, Lapidus et al. 1997; Andersen, Crespo et al. 1998; McMurray, Harrell et al. 2000; Crespo, Smit et al. 2001; Eisenmann, Bartee et al. 2002). These studies all had large sample sizes (mostly n≥1,000), although few used measures of self-reported physical activity that had been reliability or validity tested. A number of cross-sectional and prospective studies that have used objective measures of physical activity have also observed no association between physical activity and measures of adiposity (Goran, Shewchuk et al. 1998; Rowlands, Eston et al. 1999; Johnson, Figueroa-Colon et al. 2000; Vincent, Pangrazi et al. 2003; Raustorp, Pangrazi et al. 2004; Thompson, Campagna et al. 2005), particularly those that are large and those that use pedometers or accelerometers to measure physical activity. It is possible that in children, dietary intake or genetics play a more important role in determining energy imbalance and adiposity than physical activity.

An alternative interpretation of the findings from the current study is that associations were missed because physical activity has been poorly measured. Questionnaires are a tool commonly used in epidemiological studies to measure physical activity, but the limitations of this method, particularly in children, have been well documented (Morrow and Freedson 1994; Welk, Corbin et al. 2000; Ekelund, Poortvliet et al. 2001; Sirard and Pate 2001). As discussed in Chapter 2, a recent review of children's physical activity questionnaires found all measures assessed to have acceptable retest reliability (r=0.60-0.98) and approximately half showed correlations with objective measures of physical activity of r=0.50 or greater (range 0.07-0.88 for children's self-reported physical activity) (Sallis and Saelens 2000). Correlations depended on the objective measure used, with correlations highest between self-report and pedometers (r=0.88) and observations (r=0.72), although these methods were only employed in one validity study each. Correlations were moderate between self-report and heart rate monitors (median: 0.53, range: 0.17-0.77) and accelerometers (median: 0.38, range: 0.07-0.77). Most surveys showed some evidence of criterion validity, although very few studies tested this in more than one study. These findings suggest that children should be able to report their physical activity reliability and somewhat accurately. Nevertheless, this assertion cannot be confirmed in the current study due to the lack of validity and reliability data available for the questionnaire used in the ASHFS 1985. It is possible that the measures used in the current study lacked the sensitivity to "capture" light activities, such as active play after school, declines in which have been suggested as having a role in the increasing prevalence of childhood overweight and obesity (Olds 2006). These types of activities have been described as non-exercise activity thermogenesis (NEAT) and have been shown to be lower in highly sedentary, obese adults compared to highly sedentary, lean adults (Levine, Lanningham-Foster et al. 2005).

In a recent meta-analysis, Rowlands and colleagues raised the issue of how the type of physical activity measure might affect the relationship between body fatness and habitual physical activity in children (Rowlands, Ingledew et al. 2000). After assessing results from 50 studies, the authors concluded that the effect size of this relationship depended on how physical activity was measured – studies that used observational techniques (r=-0.39) or motion sensors (r=-0.18) recorded greater effect sizes than studies that used questionnaires (r=-0.14). Interestingly, of the 32 studies the authors analysed that used questionnaires to measure physical activity, 25 identified an inverse relationship between adiposity and physical activity, although the relationships tended to be weak. However, only seven of these studies reported a sample size greater than 500, 16 (50%) of these studies reported a sample size less than 100, and most were cross-sectional. While this review might suggest that the physical activity measure used in the ASHFS may be poor, the questions were deemed appropriate at the time by the experts who designed it; they were thought to be simple to complete; and children were assisted to complete the questionnaires by trained data collectors in small groups. In addition, responses to the questions seemed appropriate and patterns were consistent with findings from other studies, and responses for compulsory activities (such as school sport and physical education in primary school) were consistent between healthy weight and overweight children, as should be expected. Boys reported more physical activity than girls, and girls' physical activity decreased with age in early adolescence, both findings that have been observed previously (Trost, Pate et al. 1996; Booth, Okely et al. 2002; Kimm, Glynn et al. 2002). In addition, median values reported were plausible and logical (i.e. median values for school physical education were 60 minutes for primary school aged participants and 100 minutes for secondary school aged participants).

The relationship between physical activity and cardiorespiratory fitness in children and adolescents is complex. It is generally considered weak (Morrow and Freedson 1994; Trost 2003), however, there is evidence to suggest that the more physically active children are usually the fittest (Morrow and Freedson 1994; Rowlands, Eston et al. 1999; Ekelund, Poortvliet et al. 2001) and evidence from the training literature suggests that increased structured physical activity can result in increases in cardiorespiratory fitness (Baquet, van Praagh et al. 2003). It is generally thought that much of the variability in cardiorespiratory fitness in children is attributed to genetic differences. It is possible that the genes responsible for cardiorespiratory fitness in children may also play a role in the development of overweight and obesity.

In the current study, physical activity and cardiorespiratory fitness were generally correlated at low to moderate levels, which has been noted previously in this sample (Cleland, Venn et al. 2005). Correlations were also consistent with a meta-analysis that pooled 28 correlation coefficients from 15 studies, finding an overall correlation of r=0.17 between physical activity and cardiorespiratory fitness. The associations seen in the current study tended to be consistent, irrespective of the measure of cardiorespiratory fitness or the measure of physical activity. In particular, past week physical activity was most strongly associated with $VO2_{max}$ and PWC_{170}.

A limitation of the current study is the lack of dietary information available. While physical activity is an important component of energy balance, it is only one side of the equation (energy balance = energy intake - energy expenditure). Evidence suggests that caloric intake has a major role to play in the development of overweight and obesity (Lissner and Heitmann 1995). The lack of energy intake data in this study means that this aspect of the energy balance equation cannot be adequately considered. However, it is still important to examine the physical activity behaviours of healthy weight and overweight children.

Despite the limitations, this study had a number of important advantages over previous studies. No published reports have used a large, representative sample of Australian children. It is possible that the relationship between physical activity and adiposity may be different in Australian children due to environmental, societal and cultural differences. In addition, the self-reported measure of physical activity included information on both frequency and duration, which many studies, particularly those larger in size, do not (Raitakari, Taimela et al. 1997; Schmidt, Stensel et al. 1997; Dowda, Ainsworth et al. 2001; Eisenmann, Bartee et al. 2002). Also, the objective cardiorespiratory fitness measures allow further exploration of the relationship between cardiorespiratory fitness, physical activity and healthy weight. Additional information on sociodemographic variables, such as smoking, school type, parental smoking and SES, enabled exploration of the effect of potential confounders.

3.11 Summary

What is already known?

- Physical activity is the only easily modified element of energy expenditure, which is important for energy balance
- There is conflicting evidence about the importance of physical activity and cardiorespiratory fitness in determining weight status in children

What was done to learn more?

- 6,414 Australian children (aged 9-15 years) were surveyed as part of the Australian Schools Health and Fitness Survey (ASHFS)
- Participants completed a physical activity questionnaire and a cardiorespiratory fitness test (those aged 9, 12 or 15 years), and had their height, weight and waist girths measured
- Log binomial regression was used to calculate the ratios of prevalence (PR) of healthy weight at different levels of physical activity and cardiorespiratory fitness

What were the key results?

- The average physical activity and cardiorespiratory fitness levels of healthy weight children tended to be higher than the average levels of overweight children
- There was no difference in the prevalence of healthy weight between the most active children (≥9 hours/week) and the least active children (<3 hours/week) (PR 1.00, 95% CI: 0.97-1.03) in boys; PR 1.05, 95% CI: 1.01-1.09 in girls)
- 12 year old boys in the highest fitness third had a slightly elevated prevalence of healthy weight than those in the bottom third (PR 1.12, 95% CI: 1.03-1.22), and 15-year old girls in the highest third had a slightly elevated prevalence of health weight compared to those in the bottom third (PR 1.12, 95% CI: 1.02-1.23)

What does this study add?

- Cardiorespiratory fitness showed stronger associations with healthy weight than physical activity, although associations were modest
- While overweight prevention strategies that aim to increase physical activity and cardiorespiratory fitness levels may be beneficial, these findings suggest that physical activity and fitness appear to play only a small role in determining healthy weight
- However, given the lack of precise energy expenditure measures, it seems most likely that *energy balance* is key for healthy weight

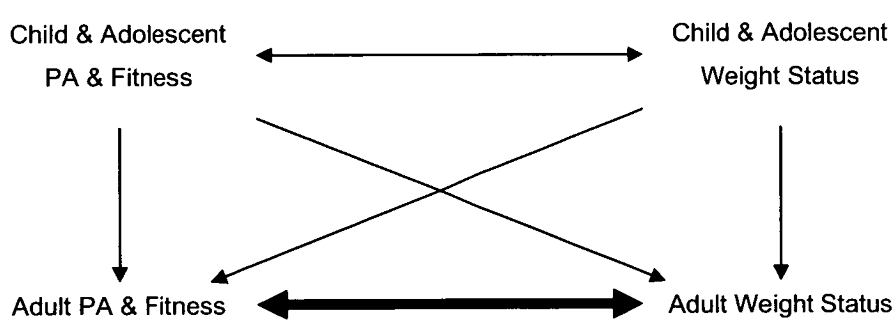
<u>CHAPTER 4 – ARE ACTIVE, FIT ADULTS MORE LIKELY TO BE A HEALTHY WEIGHT?</u>

4.1 <u>Introduction</u>

In the previous chapter, the cross-sectional association between children's physical activity, cardiorespiratory fitness and weight status was examined. Findings suggested that children's self-reported physical activity was not associated with weight status, although cardiorespiratory fitness showed a stronger association. Sociodemographic factors, while related to healthy weight at weak levels, had little influence on the association between healthy weight and physical activity.

In this chapter, the cross-sectional association between physical activity, cardiorespiratory fitness and weight status in young adulthood is examined, for those followed up after 20 years at age 26-36 years (Figure 19). It is important to do this in order to better understand the relationship between physical activity and weight status from childhood into adulthood. While a number of other studies have examined cross-sectional associations between the weight status of adults and their current physical activity, none have done so using an objective measure of physical activity in such a large sample of young adults and none have had the additional advantage of using an objective measure of cardiorespiratory fitness.

Figure 19: Conceptual model of the relationships between physical activity, fitness & weight status from childhood & adolescence into adulthood



Adapted from Blair et al (1989)

4.2 Literature Review

The following section provides a detailed and critical review of the literature that examines the relationship between overweight and obesity, physical activity and cardiorespiratory fitness in adults. First, the relationship between physical activity and adiposity is examined. This section involves a review of intervention and observational studies that have examined this relationship prospectively and cross-sectionally. The relationship between physical activity, cardiorespiratory fitness and adiposity is then discussed.

4.2.1 Physical Activity & Adiposity in Adults

A number of studies have attempted to examine the relationship between adiposity and physical activity in adults. The majority of these studies have been cross-sectional and most employ self-reported measures of physical activity with limited reliability or validity properties. Few intervention studies that aim to directly disentangle this relationship exist. A recent systematic review (Fogelholm and Kukkonen-Harjula 2000) concluded that while cross-sectional and retrospectively-reported associations were evident, the predictive value of physical activity for future overweight and obesity was limited. This section examines both intervention and observational studies that have attempted to assess this relationship.

4.2.1.1 Intervention Studies in Adults

While there are many randomised controlled trials examining physical activity as a treatment for overweight or obesity (Ross, Dagnone et al. 2000; Jakicic, Marcus et al. 2003; Ross, Janssen et al. 2004; Slentz, Duscha et al. 2004), there are few studies that examine the effect of physical activity on weight gain or obesity prevention. A recent review concluded that not only are there limited numbers of these studies, but those that do exist have limitations that prevent the ability to draw firm conclusions (Wareham, van Sluijs et al. 2005). In addition, most of these studies have focused broadly on obesity or CVD prevention and therefore incorporate multi-component strategies, such both physical activity and nutrition interventions. Combined strategies such as these make it impossible to determine whether findings are related to the physical activity component or another component altogether.

4.2.1.2 Observational Studies in Adults

A large number of observational studies exist that examine the association between adiposity and physical activity in adults. This body of literature has been summarised in this thesis as a number of tables (Appendix 14a). Studies are presented according to study design (prospective or cross-sectional) and the measure of physical activity used (objective or self-reported). The tables include information on the country of the study, the authors and year of the study, the number and age of participants (stratified by sex if possible), the sampling technique used (probability or non-probability sample and further detail if available) the measure of physical activity, the measure of adiposity, definitions of overweight/obesity (if assessed), significant findings, statistical adjustments, length of follow-up (for prospective studies), and an estimate of the overall effect. A positive (+) overall effect indicates that physical activity is positively associated with the measure of adiposity, a negative (-) overall effect indicates a negative relationship, a null (0) effect indicates no association, and an inconsistent (?) effect indicates that mixed results were observed (i.e. a combination of negative and positive associations with no clear trends). Whether the measure used had undergone reliability and validity testing was also noted (not included in table). Studies that focused on special population groups (i.e. Pima Indians, athletes, persons with a disability) were generally not included, unless otherwise specified.

Overall Findings

A summary of the overall findings of these studies is presented in Table 30. The total number of findings presented in this table is larger than the number of studies presented in the appendix because some findings were presented separately for men and women while others were presented combined; each reported finding contributes to the total number of findings in the table below.

Table 30: Summary of associations observed from prospective & cross-sectional studies that have examined the association between objective & self-reported physical activity & adiposity in adults

Overall Association Observed	Prospective Studies		Cross-Sectional Studies	
	Objective PA % (n/N)	Self-Reported PA % (n/N)	Objective PA % (n/N)	Self-Report PA % (n/N)
Nil	50.0 (1/2)	13.6 (3/22)	9.1 (1/11)	10.3 (3/29)
Negative	0.0 (0/2)	50.0 (11/22)	90.9 (10/11)	65.5 (19/29)
Positive	0.0 (0/2)	0.0 (0/22)	0.0 (0/11)	0.0 (0/29)
Inconclusive	50.0 (1/2)	36.4 (8/22)	0.0 (0/11)	24.1 (7/29)

The current body of evidence suggests an inverse association between physical activity and adiposity in adults, a finding particularly evident in cross-sectional studies using objective measures of physical activity. While the two prospective studies examining physical activity and adiposity using objective measures do not provide convincing evidence of an association, the combined evidence from prospective and cross-sectional studies using self-reported measures and cross-sectional studies using objective measures suggest the existence of an inverse association. While it is possible that self-reported measures of physical activity are imprecise and overestimate associations, this seems unlikely given the consistent findings across prospective and cross-sectional studies, and in cross-sectional studies using objective measures. It is plausible that small imbalances in energy intake and expenditure over time – which are likely responsible for weight gains (Hill, Wyatt et al. 2003) – are difficult to detect in longitudinal studies that measure energy intake and expenditure for short periods of time on only a few occasions, even using the most precise measures currently available.

Prospective Studies Using Objective Measures of Physical Activity

Of the studies examined, only two were prospective studies that used objective measures of physical activity, and one of those was in a special population group (Pima Indians), but was included here due to a dearth of other available studies. This study assessed physical activity energy expenditure using the DLW technique in 92 healthy Pima Indian adults aged 19-70 years (Tataranni, Harper et al. 2003). After four years of follow-up, the investigators observed no association between physical activity energy expenditure or physical activity level at baseline and change in body weight. Another study assessed physical activity energy expenditure by individually-calibrated heart rate monitoring in 739 adults in the UK (Ekelund, Brage et al. 2005). Physical activity energy expenditure predicted decreases in fat mass in the younger adults, while in older adults, physical activity energy expenditure was associated with a gain in body weight, which the authors explained by increases in fat mass and fat free mass. The authors of both studies speculate that the role of energy intake may be more important in the pathogenesis of obesity than the role of energy expenditure, and that lower levels of physical activity in obese subjects are likely a result, rather than a cause, of weight gain.

Prospective Studies Using Self-Reported Measures of Physical Activity

Many studies assessed prospectively the relationship between self-reported physical activity and adiposity (Appendix 14a, Table 15). Due to the large number of published reports that fall into this category, only those that had a large sample size (n>500) are presented here. Of the 16 studies examined, 15 included men and 12 included women. Results from studies that included men were equivocal: six studies observed a negative association between physical activity and adiposity (Rissanen, Heliovaara et al. 1991; French, Jeffery et al. 1994; Coakley, Rimm et al. 1998; Thune, Njolstad et al. 1998; Schmitz, Jacobs et al. 2000; Koh-Banerjee, Chu et al. 2003), three observed no association (Lee, Hsieh et al. 1995; Paeratakul, Popkin et al. 1998; Petersen, Schnohr et al. 2004) and six reported inconsistent results (Williamson, Madans et al. 1993; Ching, Willett et al. 1996; Haapanen, Miilunpalo et al. 1997; Kahn, Tatham et al. 1997; Sherwood, Jeffery et al. 2000; Droyvold, Holmen et al. 2004). In women, results were more supportive of the existence of a prospective association between physical activity and adiposity: eight of the 11 studies observed an inverse association (Rissanen, Heliovaara et al. 1991; French, Jeffery et al. 1994; Paeratakul, Popkin et al. 1998; Thune, Njolstad et al. 1998; Schmitz, Jacobs et al. 2000; Sherwood, Jeffery et al. 2000; Hu, Li et al. 2003; Droyvold, Holmen et al. 2004), one reported no association (Petersen, Schnohr et al. 2004) and three reported inconsistent results (Williamson, Madans et al. 1993; Haapanen, Miilunpalo et al. 1997; Kahn, Tatham et al. 1997). Three studies also examined the relationship between sedentary behaviours and adiposity in men, with one study finding no association (Ching, Willett et al. 1996) and the other two finding a positive association (Coakley, Rimm et al. 1998; Koh-Banerjee, Chu et al. 2003). One study assessed the prospective relationship between sedentary behaviours and adiposity in women and saw a positive association between television viewing/video use, sitting and the likelihood of obesity (Hu, Li et al. 2003). The use of reliable or valid measures of physical activity did not appear to influence the findings, with no obvious trends observed according to the measure used.

Cross-Sectional Studies Using Objective Measures of Physical Activity

A limited number of studies have assessed the relationship between objectively measured physical activity and adiposity cross-sectionally, with findings generally supportive of the existence of an inverse association (Appendix 14a, Table 16). Of the ten studies assessed, only three had sample sizes greater than 200 (Westerterp and Goran 1997; Wyatt, Peters et al. 2005; Yoshioka, Ayabe et al. 2005), although one of these was a combination of results from 22 smaller studies (Westerterp and Goran 1997). Studies used pedometers (Tudor-Locke, Ainsworth et al. 2001; Chan, Spangler et al. 2003; Whitt, Kumanyika et al. 2003; Thompson, Rakow et al. 2004; Hornbuckle, Bassett et al. 2005; Wyatt, Peters et al. 2005), accelerometers (Cooper, Page et al. 2000; Whitt, Kumanyika et al. 2003; Yao, Lichtenstein et al. 2003; Yoshioka, Ayabe et al. 2005) and the DLW technique (Westerterp and Goran 1997) to measure physical activity. Nine studies in women observed an inverse association (Cooper, Page et al. 2000; Tudor-Locke, Ainsworth et al. 2001; Chan, Spangler et al. 2003; Whitt, Kumanyika et al. 2003; Yao, Lichtenstein et al. 2003; Thompson, Rakow et al. 2004; Hornbuckle, Bassett et al. 2005; Wyatt, Peters et al. 2005; Yoshioka, Ayabe et al. 2005) while only one study observed no association (Westerterp and Goran 1997). Similar results were evident in men, with all seven studies observing an inverse relationship between objectively measured physical activity and adiposity (Westerterp and Goran 1997; Cooper, Page et al. 2000; Tudor-Locke, Ainsworth et al. 2001; Chan, Spangler et al. 2003; Yao, Lichtenstein et al. 2003; Wyatt, Peters et al. 2005; Yoshioka, Ayabe et al. 2005).

Cross-Sectional Studies Using Self-Reported Measures of Physical Activity

Table 17 (Appendix 14a) provides a summary of cross-sectional studies that have examined the relationship between physical activity and adiposity using self-reported measures of physical activity. Due to the large number of published reports that fall into this category, only those that had a large sample size (n>1,000) and reported on young adults are presented here. Results from 10 of 17 studies in men and 11 of 17 studies in women suggest that a cross-sectional inverse relationship exists between physical activity and adiposity (Sallis, Haskell et al. 1986; Bauman and Owen 1991; Mensink, Heerstrass et al. 1997; Salmon, Bauman et al. 2000; Ball, Owen et al. 2001; King, Fitzhugh et al. 2001; Gutierrez-Fisac, Guallar-Castillon et al. 2002; Hu, Pekkarinen et al. 2002; Cameron, Welborn et al. 2003; Bernstein, Costanza et al. 2004). Two studies each in men (Kronenberg, Pereira et al. 2000; Liebman, Pelican et al. 2003) and women (Hu, Pekkarinen et al. 2002; Liebman, Pelican et al. 2003) found no association, while five studies in men and four in women reported inconsistent results (Folsom, Caspersen et al. 1985; Vioque, Torres et al. 2000; Lahti-Koski, Pietinen et al. 2002; McCarthy, Gibney et al. 2002).

A number of cross-sectional studies also examined the relationship between television viewing and adiposity. There was strong evidence for a positive association between television viewing and adiposity both in men and women (Tucker and Friedman 1989; Kronenberg, Pereira et al. 2000; Salmon, Bauman et al. 2000; Vioque, Torres et al. 2000; McCarthy, Gibney et al. 2002; Cameron, Welborn et al. 2003; Liebman, Pelican et al. 2003). While many of the measures used were reliable (Folsom, Caspersen et al. 1985; Sallis, Haskell et al. 1986; Mensink, Heerstrass et al. 1997; Kronenberg, Pereira et al. 2000; Salmon, Bauman et al. 2000; Ball, Owen et al. 2001; Cameron, Welborn et al. 2003), only some had acceptable validity (Mensink, Heerstrass et al. 1997; Kronenberg, Pereira et al. 2000; Salmon, Bauman et al. 2000; Ball, Owen et al. 2001; Cameron, Welborn et al. 2003). However, whether the sedentary behaviour measures used in these cross-sectional studies was deemed reliable or valid appeared to have little influence on the findings.

Systematic Reviews

Two systematic reviews have recently summarised literature on physical activity and weight gain in adults, one focusing on papers published until 2000 (Fogelholm and Kukkonen-Harjula 2000) and the other focusing on papers thereafter until 2005 (Wareham, van Sluijs et al. 2005). The first review concluded that there was inconsistent evidence from prospective studies of the predictive effect of baseline physical activity on subsequent weight gain (Fogelholm and Kukkonen-Harjula 2000). The second review concluded that of the prospective studies that used self-reported measures of physical activity, the magnitude of the effect was small where an inverse association between physical activity and weight gain was seen. Studies that used objective measures of physical activity were scarce and firm conclusions could not be drawn. The authors suggested three interpretations of their unexpected findings: measurement error – physical activity is an important factor in weight gain prevention but the true association is not seen because measures are too insensitive; reverse causality – less weight gain may lead to better exercise adherence; and confounding – self-reported physical activity may be a proxy for a generally healthy lifestyle. Another possible interpretation is that physical activity is not as important as excess energy intake or genes in the pathogenesis of weight gain over time. It is likely that a combination of each of these factors contributes to the weak associations generally seen between physical activity and adiposity in adults in well-conducted prospective studies.

4.2.2 Physical Activity, Cardiorespiratory Fitness & Adiposity

The relationship between physical activity, cardiorespiratory fitness and overweight and obesity is complex. Physical activity is a behaviour influenced by personal, social and environmental factors, while cardiorespiratory fitness is a physical attribute influenced by both behaviour and genes. Weight status is influenced by an individual's energy intake and energy expenditure (including physical activity, resting metabolic rate and thermogenesis), with imbalances resulting in weight gain or loss, depending on the direction of the imbalance.

It is generally well accepted that while cardiorespiratory fitness has a genetic component that accounts for approximately 10-25% of variability (Bouchard, Dionne et al. 1992), physical activity plays a major role in determining cardiorespiratory fitness in adults. Most studies observe moderate to strong correlations (r=0.35-0.81) between self-reported measures of physical activity and cardiorespiratory fitness in adults (Williams 2001). A recent review summarised 10 studies that examined the construct validity of pedometers with fitness measures and concluded that the magnitude and direction of the relationship varied depending on the measure of cardiorespiratory fitness used (Tudor-Locke, Williams et al. 2004). Median correlation coefficients for the relationship between steps and cardiorespiratory fitness were r=0.22 for estimated $VO2_{max}$, r=0.41 for a timed treadmill test and r=0.69 for a 6-minute walk test. These findings are not surprising given that pedometers measure ambulatory activity which is more likely to be reflected in the treadmill and walking tests.

Numerous studies have observed an inverse association between cardiorespiratory fitness and adiposity in adults. Many studies also note that the association between cardiorespiratory fitness and adiposity is stronger than the association between physical activity and adiposity. Some authors have argued that this is because physical activity is more difficult to measure and therefore true associations are masked. Others have argued that because physical activity is a behaviour, while cardiorespiratory fitness is a physical attribute with genetic influences, their relationships with adiposity should be expected to be different.

Most studies that have assessed this relationship have used self-reported measures of physical activity. Authors of a cross-sectional study of 1,664 adults concluded that fitness had more of an association with obesity risk than self-reported physical activity (McMurray, Ainsworth et al. 1998). In addition, the authors concluded that only physical activity of a sufficient intensity to increase fitness had the potential to reduce CVD risk factors, including obesity. In a sub-sample of 576 low-fit individuals, similar increases in physical activity were seen between those who increased their fitness and those whose fitness did not change after a 9-week exercise intervention. Interestingly, only those participants whose fitness increased saw a reduction in percent body fat, while those whose fitness did not change saw an increase in percent body fat.

Subjects (n=937) from the Health and Religion Project completed the Pawtucket Heart Health Step Test to estimate cardiorespiratory fitness and completed a physical activity questionnaire that asked about frequency of vigorous exercise of 20 minutes or more duration in the past month (Eaton, Lapane et al. 1995). Estimated $VO2_{max}$ showed stronger inverse associations with BMI in both men (r=-0.63) and women (r=-0.65) than physical activity (r=-0.11 and r=-0.09, respectively). Fitness was also a significant predictor of BMI in both men and women, while physical activity was not.

In a population-based study of 609 Norwegian adults aged 20-61 years, cardiorespiratory fitness was estimated from a graded submaximal or maximal exercise cycle test and leisure and occupational physical activity were estimated from a self-completed questionnaire (Lochen and Rasmussen 1992). In men, neither cardiorespiratory fitness nor physical activity was correlated with BMI. In women, cardiorespiratory fitness was positively correlated with BMI at low levels.

However, cardiorespiratory fitness significantly predicted BMI in a regression model in both men and women, while physical activity did not.

Two smaller studies have used objective measures to estimate physical activity. In a study of older adults (n=116), physical activity energy expenditure was measured using the DLW technique and cardiorespiratory fitness using a graded treadmill test (Dvorak, Tchernof et al. 2000). Participants were categorised into four groups based on median splits: high fitness/high physical activity, high fitness/low physical activity, low fitness/high physical activity, low fitness/low physical activity. Those with a high cardiorespiratory fitness, independent of their physical activity energy expenditure, showed lower levels of body weight, total body fat, fat mass, trunk fat mass, percent body fat, and waist circumference. Interestingly, those in the high cardiorespiratory fitness but low physical activity group had more favourable adiposity characteristics than those who had low cardiorespiratory fitness but high physical activity energy expenditure. These findings suggested that cardiorespiratory fitness was more important than physical activity in predicting adiposity characteristics.

In a Japanese study of 222 healthy adult volunteers aged 20-62 years, cardiovascular fitness was estimated using a submaximal cycle test and physical activity was estimated using a Calorie Counter accelerometer, which estimates kilocalories per day and steps per day (Suzuki, Yamada et al. 1998). Cardiorespiratory fitness was more strongly associated with percent body fat and BMI than physical activity in both men and women. In fact, physical activity was positively associated with BMI in both men and women at statistically significant levels. Comparisons between good, average and poor categories of cardiorespiratory fitness were also made. Significant differences in adiposity were noted between the good and poor categories and between the poor and average categories for both men and women. No difference was noted between the average and good categories in either sex. Results for comparison of physical activity categories were generally inconsistent, but comparisons between the light and medium categories did show significant differences in BMI and percent body fat, in the expected direction.

Overall, results from studies that have used both laboratory and field measures of cardiorespiratory fitness and both self-reported and objectively measured physical activity consistently demonstrate stronger associations between cardiorespiratory fitness and adiposity than between physical activity and adiposity. While some authors have suggested that these findings result from imprecise physical activity measures, which may account for some of the differences, two smaller studies that used objective measures of physical activity (one using a "gold standard" technique, DLW) observed similar findings. This suggests that the association may indeed be stronger for cardiorespiratory fitness than for physical activity, with three likely explanations. First, it is plausible that the genes that influence cardiorespiratory fitness are also associated with the genes that influence regulation of adiposity. For instance, those individuals whose cardiorespiratory fitness is easily influenced by physical activity may also show stronger relationships between fitness and adiposity. Second, it is possible that only physical activity of a high enough intensity to influence cardiorespiratory fitness can also influence adiposity. This seems plausible because the effects of higher intensity physical activity on resting metabolic rate may be longer lasting than the effects of lower intensity physical activity. Additionally, higher intensity physical activity may be more likely to result in increases in lean muscle mass, which is associated with increases in resting metabolic rate (Speakman and Selman 2003). Third, misclassification error in physical activity measures, particularly self-reported measures, is likely to result in an underestimation of associations and bias findings towards the null. It is likely that objective measures of cardiorespiratory fitness are a better reflection of energy expenditure and therefore observe stronger associations with adiposity than physical activity.

4.3 Aims & Research Questions

No published reports have examined the association between physical activity and adiposity using pedometers to objectively measure physical activity in a large, population-based sample of Australian adults. In fact, the largest study published to date that has examined this relationship using pedometers included a sample of 730 participants from a wide age range in Colorado, USA. This study also estimated BMI based on self-reported measures of height and weight, which may have resulted in some misclassification. Few studies have had the added advantage of being able to examine the association of cardiorespiratory fitness with adiposity and physical activity in the same sample. The aim of this chapter was to determine whether physically active or fit subjects were more likely to be a healthy weight than less physically active or fit subjects in a sample of young Australian adults participating in the CDAH follow-up study, the 20 year follow-up of the ASHFS 1985. The specific research questions were:

1. Are physically active adults more likely to be a healthy weight than less active adults?
2. Are fitter adults more likely to be a healthy weight than less fit adults?

4.4 Methods

The following section details the methodology involved in this study. First, the sample and participants are discussed. Second, the measures used in the study are summarised (more detail is provided in Chapter 2). Finally, the statistical methods used in this chapter are described.

4.4.1 Participants

The subjects for this chapter were participants who were aged 9-15 years in the ASHFS 1985 and who also participated in the CDAH follow-up study during 2004-5. The sample is described in detail in Chapter 2. Briefly, 8,498 children aged 7-15 years were randomly selected from 109 government, Catholic and independent schools from all states and territories in Australia. The first stage of sampling involved selecting schools with a probability proportional to size, with the second stage employing simple random sampling to select children. While the ASHFS 1985 was not planned as a cohort study, researchers at the MRI in Hobart, Australia, re-traced 80.4% of the original sample. Of these, 5,159 (75.5%) indicated an interest in participating in a follow-up study and agreed to enroll in the study by completing a brief enrolment questionnaire and providing informed written consent. During 2004-5, 2,053 (39.8%) of these participants attended a CDAH clinical assessment at age 26-36 years.

4.4.2 Measures

The measurements at follow-up are described in detail in Chapter 2. Briefly, a trained technician measured height to the nearest 0.1cm using a Leicester stadiometer; weight to the nearest 0.1kg using Heine digital scales; and waist girth to the nearest 0.1cm using a Lufkin non-stretch steel measuring tape. Participants recorded their total daily steps as measured by a Yamax Digiwalker pedometer (model DW-200), which was worn over the right hip for seven days. The long version of the International Physical Activity Questionnaire (IPAQ-L) was completed, an instrument that has been shown to have acceptable validity and a high level of reliability in a 12-country study (Craig, Marshall et al. 2003). Sociodemographic information (occupation, highest level of education, marital status, smoking status, and in females, number of children) was collected via a general self-completed questionnaire. Participants undertook a PWC_{170} cycle ergometer test, which involved administering increasing workloads over three, four-minute periods to raise heart rate within predetermined ranges. The number of participants providing data used in this chapter is presented in Table 31.

Table 31: Number of participants providing data in the CDAH follow-up study

Measure	n
BMI only	2,053
BMI + Pedometers	1,640
BMI + IPAQ-L	1,883
BMI + Pedometers + IPAQ-L	1,599
BMI + Fitness	1,727
BMI + Fitness + Pedometers	1,448
BMI + Fitness + IPAQ-L	1,639
BMI + Fitness + Pedometers + IPAQ-L	1,412

4.4.3 Statistical Methods

Definitions

Participants were classified as a healthy weight if their BMI was less than $25kg/m^2$. To examine the effects of using an alternate definition of healthy weight and overweight, analyses were also conducted using waist circumference <94cm in men and <80cm in women to define healthy weight. Because healthy weight defined using BMI was the main outcome, the results of these alternate analyses are mostly presented in the appendixes, although some are included in the general text where results differ to those using BMI.

For the pedometer measures, four unlikely daily readings exceeded 80,000 steps and were excluded from the analyses. There is evidence to suggest that a minimum wear time of eight hours per day is adequate to estimate average steps (Schmidt, Blizzard et al. In Press). Of the remaining 13,034 days of pedometer records, 260 (2.0%) records included a daily wear time of less than 8 hours and 353 readings (2.7%) did not have adequate information to calculate daily wear time; these data were therefore excluded from the analyses. Average daily steps were then calculated from the remaining 12,421records, for a total of 1,860 participants.

There is additional evidence to suggest that a minimum of three days of pedometer readings (Tudor-Locke, Burkett et al. 2005) is sufficient to estimate average steps. This criterion was increased to four days in these analyses because a large proportion of the sample met this criterion and doing so provides greater confidence in the point estimates. A small proportion of participants (n=14, 0.8%) did not have adequate information to calculate number of days worn and were therefore excluded from further analyses.
Most participants recorded seven days of pedometer readings, with only 0.6% recording less than 4 days worth of readings (Table 32). There was no significant difference in average daily steps between those who recorded less than four days pedometer readings, and those who recorded four, five, six or seven days readings (p=0.20). Those who recorded less than four days worth of readings were excluded from the analyses, leaving 1,849 records for analysis.

Table 32: Number of days pedometer readings recorded by young Australian adults & mean & standard deviation daily steps in the CDAH follow-up study

Number of Days	n	%	Mean	SD
<4 days	11	0.6	9471.9	6030.1
4 days	16	0.9	7668.0	4130.7
5 days	17	0.9	9879.3	5969.6
6 days	39	2.1	8046.4	3362.0
7 days	1,777	95.5	9055.8	3273.8

Average daily steps recorded by pedometers were treated as both a continuous and categorical variable. For the categorical analysis, participants were classified according to proposed public health categories defined by Tudor-Locke (Tudor-Locke and Bassett 2004): sedentary (<5,000 steps/day), low active (5,000-7,499 steps/day), somewhat active (7,500-9,999 steps/day), active (10,000-12,499), and high active (≥12,500 steps/day). These preliminary classifications were developed based on physical activity guidelines and a review of the literature. While the guidelines have not been extensively evaluated, there currently exists no other accepted classification system for average daily steps.

Data from the IPAQ-L were treated as continuous and categorical variables. First, time (minutes) and energy (METs) spent within each domain of physical activity (leisure, occupational, commuting and household/yard) was calculated. Second, time (minutes) spent at each intensity of physical activity (walking, moderate and vigorous) was calculated. Third, total time (minutes) and energy (METs) in all activities was calculated (total time and total METs). Lastly, following the IPAQ protocol (www.ipaq.ki.se), three categories of activity were derived: low, moderate and high. These categories are described in Table 33.

Table 33: Classification of self-reported physical activity using the IPAQ-L scoring protocol

1. Low Active	2. Moderate Active	3. High Active
No activity is reported	3 or more days of vigorous-intensity activity of at least 20 minutes per day	Vigorous-intensity activity on at least 3 days and accumulating at least 1500 MET-minutes/week
OR	OR	OR
Some activity is reported by not enough to meet Categories 2 or 3	5 or more days of moderate-intensity activity and/or walking of at least 30 minutes per day	7 or more days of any combination of walking, moderate- or vigorous-intensity activities accumulating at least 3000 MET-minutes/week
	OR	
	5 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum of at least 600 MET-min/week	

Because a high proportion of participants in the current study were categorised as high active (54%) using this classification system, the median value was used to dichotomise this category into two subcategories: high active and very high active. Physical activity data from the IPAQ-L can therefore be presented in four ways:

1. Categorically – low, moderate, high, very high
2. Continuously by time spent (minutes) at each intensity – walking, moderate, vigorous
3. Continuously by time (minutes) and energy (METs) spent in each domain – leisure, occupational, commuting, household/yard
4. Continuously by total physical activity – total time (minutes) and total energy expenditure (METs)

The IPAQ-L also asked participants to record time spent sitting in the past week. In addition to the IPAQ-L, participants were asked to record the time spent watching television, DVDs and videos in the past week and the time spent using computers, video games and the internet in past week. All three measures of sedentary behaviour were treated as continuous variables (hours per day or week) and as categorical variables. Categories were based on logically determined cutpoints that could easily have public health application. Sitting was categorised as <20 hours/week, 20-40 hours/week, 40-60 hours/week, or >60 hours/week. Television viewing was categorised as <1 hour/day, 1-2 hours/day, 2-3 hours/day or >3 hours/day. Computer use was categorised as <10 hours/week, 10-20 hours/week, 20-30 hours/week, and >30 hours/week. In some instances, tertiles of physical activity or sedentary behaviour are used.

Cardiorespiratory fitness estimated from the PWC_{170} cycle ergometer test was treated as a continuous and categorical variable. Categories were determined using tertile and quartile splits to generate thirds and quarters of cardiorespiratory fitness. The lower thirds or quarters represent the lowest levels of cardiorespiratory fitness while the higher thirds or quarters represented the highest levels of cardiorespiratory fitness.

Descriptive Analysis

Pregnant women were excluded from all analyses (n=68). Descriptive statistics (proportions, means and standard deviations, or medians and inter-quartile ranges) were used to characterise adiposity, cardiorespiratory fitness and physical activity in this sample.

To compare the means of physical activity and adiposity characteristics between sexes, two-sample (unpaired) t-tests were used to determine whether differences existed, where equal variances were assumed. Where variances were unequal, Wilcoxan rank sum tests were used. Partial correlation coefficients adjusted for age were calculated to compare BMI and waist circumference as measures of adiposity. Chi-squared tests were used to determine whether sex differences in physical activity participation existed.

BMI and waist girth were compared to gain an understanding of the relationship between the measures. To do this, partial correlation coefficients adjusted for age were calculated, stratified by sex. Objectively measured and self-reported physical activity were also compared to gain an understanding of their relationship to each other by calculating age-adjusted partial correlation coefficients, based on ranked data. In addition, the proportion of participants classified as low, moderate, high and very high active based on self-reported physical activity in the IPAQ-L was compared with the proportion of participants classified as sedentary, low active, somewhat active, active and high active based on average daily steps categories proposed by Tudor-Locke (2004). This comparison was conducted in order to understand the differences in classification when using self-reported and objective techniques to measure physical activity.

To explore the relationship between physical activity and cardiorespiratory fitness, age-adjusted partial correlation coefficients were calculated. This analysis used data from the PWC_{170} cycle ergometer test and from the various physical activity measures.

Bivariable & Multivariable Analysis

To determine whether healthy weight was more prevalent in physically active or fit adults than in less physically active adults, one-way analysis-of-variance (ANOVA) was used for continuous physical activity and fitness data, where the assumption of equal variances was met. Due to the highly skewed nature of this data, this assumption was rarely met (unequal variances existed), therefore the Kruskal-Wallis test was used in the majority of cases. The continuous physical activity variables used were the intensity (walking, moderate, vigorous) variables, the total physical activity variables (total minutes and total METs), each of the physical activity domains (leisure, occupational, commuting and household/yard).

For categorical physical activity and fitness data, a bivariable log binomial model was used to estimate prevalence ratios of healthy weight and overweight across physical activity and fitness variables. Bivariable log binomial models were also constructed to explore the association between sociodemographic variables and the prevalence of healthy weight. Sociodemographic variables that reached statistical significance were then entered into a multivariable model to examine their effect on the association between physical activity or fitness and healthy weight. Crude and adjusted prevalence ratios and 95% confidence intervals are presented.

In addition, the combined effect of physical activity and cardiorespiratory fitness on the prevalence of healthy weight was examined. This was done by categorising participants as low, moderate or high physical activity and as low, moderate or high cardiorespiratory fitness, based on tertile splits of activity and fitness. Prevalence ratios and 95% confidence intervals derived from a log binomial model are presented to demonstrate the prevalence of healthy weight and overweight according to each combination of physical activity and cardiorespiratory fitness category (i.e. low activity-low fitness, low activity-moderate fitness, low activity-high fitness, etc). Similar analyses were conducted to examine the combined effect of television viewing and cardiorespiratory fitness on the prevalence of healthy weight.

4.5 Characteristics of Participants

Table 34 presents the sociodemographic characteristics of participants, stratified by sex. The majority of participants were in full-time employment (67.4%). Approximately half the participants were in managerial or professional occupations, slightly higher than the population average for 25-34 year olds (Australian Bureau of Statistics 2001). More women than men were employed in white collar occupations, while more men than women were employed in blue collar occupations, as observed in the general population for a similar age. Only a small proportion of men and 17% of women were not in the labour force. Of the women who were not in the labour force, 87% reported their employment status as home duties (data not shown). More women than men reported completing a university or higher degree, while more men than women reported completing a diploma or vocational education, consistent with occupation levels. Approximately one third of participants completed school only. Education levels were higher in this sample than in the general population, with 20% of 25-34 year old Australians having attained a university or higher degree and 27% having completed a diploma or vocational education (Australian Bureau of Statistics 2001).

There was little difference in the reported marital status of men and women. Over half the sample were married, marginally higher than the population average for 25-34 year olds of 44.2% and 47.5% of men and women respectively (Australian Bureau of Statistics 2001). Approximately 15% were in a de facto relationship, similar to the population average of 16.5% of men and 16.3% of women. Just under a third were single and a very small proportion was separated or divorced, less than the national average for 25-34 year olds of 6.0% of men and 9.0% of women (Australian Bureau of Statistics 2001). Approximately 20% of participants were current daily smokers, similar to the national average (White, Hill et al. 2003). Fifty percent of women had not had children, and 10% had three or more children. The average birth rate in this sample was 1.69 births per woman, compared with the population average of 1.75 births per woman (Australian Bureau of Statistics 2003). More than 90% of participants were born in Australia, compared with 75% nationally (Australian Bureau of Statistics 2001).

Overall, the differences noted between the participants in the CDAH study and population averages for a similar age group were marginal. While CDAH participants appear to be more highly educated and employed in higher level occupations than the general population, many other characteristics are similarly represented.

Table 34: Sociodemographic characteristics of young adults in the CDAH follow-up study, by sex

Characteristic	**Men**		**Women**	
	n	**%**	**n**	**%**
Occupation Level				
Manager/professional	568	55.7	615	50.6
White collar	83	8.1	337	27.7
Blue collar	333	32.7	59	4.9
Not in labour force	36	3.5	205	16.9
Education				
University/higher degree	378	37.4	559	46.1
Diploma/vocational	370	36.6	302	24.9
School only	264	26.1	352	29.0
Marital Status				
Single	310	30.6	303	24.7
Married	524	51.7	693	56.5
De Facto	159	15.7	186	15.2
Separated/Divorced	21	2.1	44	3.6
Widowed	0	0	1	0.1
Smoking				
Non-Smoker	579	68.1	678	71.8
Occasional Smoker	86	10.1	76	8.1
Daily Smoker	185	21.8	190	20.1
Parity				
No children	-	-	631	49.0
1 child	-	-	236	18.3
2 children	-	-	293	22.8
3+ children	-	-	127	9.9
Country of Birth[a]				
Australia	806	92.6	890	94.5
Outside Australia	64	7.4	52	5.5

[a] Country of birth data only available for participants aged 9-15 years in the ASHFS 1985

4.6 The Outcome Measure: Adiposity

The following section describes average values for adiposity measures in adults who participated in follow-up in the CDAH follow-up study. It presents the prevalence of healthy weight, overweight and obesity in this sample, using BMI and waist circumference as methods of classification.

4.6.1 Measures of Anthropometry

Average values for weight, height, BMI and waist girths are presented in Table 35. Men on average were significantly heavier, taller, and had larger BMI values and waist girths. BMI was highly correlated with waist circumference in men and women (*r*=0.93 and *r*=0.92, respectively, suggesting that in this sample, BMI is an appropriate estimate of fatness.

Table 35: Mean (standard deviation) for measures of anthropometry in young Australian adults

Measure of	**Men**			**Women**			**p**[a]
Anthropometry	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	
Weight	983	85.8	(15.1)	998	69.0	(15.4)	<0.01*
Height	982	179.7	(6.8)	999	165.8	(6.3)	<0.01
BMI	982	26.6	(4.3)	998	25.1	(5.3)	<0.01
Waist	983	89.7	(10.6)	997	78.1	(11.3)	<0.01

[a] p-values derived from Kruskal-Wallis test except for those denoted (*), derived from one-way ANOVA

4.6.2 Prevalence of Healthy Weight, Overweight & Obesity

Using BMI to classify weight status, the proportion of overweight and obesity was strikingly similar to that seen in the AusDiab study for 25-34 year olds (Cameron, Welborn et al. 2003) (Table 36). When using waist circumference to classify weight status, similar results to the AusDiab study were mostly observed, although the prevalence of overweight and obesity was marginally lower in CDAH study participants. It is plausible that differences in measurement of waist circumference are responsible for these differences. For instance, in the AusDiab study, waist circumference was measured between the lower border of the ribs and the iliac crest, while in the CDAH study the measurement was taken at the narrowest point between the lower coastal (10^{th}) rib border and the iliac crest.

Using waist circumference rather than BMI to define weight status resulted in fewer women being deemed overweight but little difference in the proportion of women deemed obese. While only a marginal difference in the proportion of men deemed obese was observed using waist circumference rather than BMI to define obesity, markedly fewer men were deemed overweight. This suggests that waist circumference may be a better indicator of visceral fat than BMI, which makes no distinction between lean and fat body mass. Because of these differences, associations between physical activity and healthy weight were analysed using both the BMI and waist circumference cutpoints. Results for analyses using waist circumference as a cut point are generally reported in the Appendix, unless the results differ markedly.

Table 36: Prevalence of healthy weight[a], overweight & obesity defined by BMI &waist circumference in young Australian adults in the CDAH follow-up study & the AusDiab study

Weight Status	CDAH				AusDiab	
	Men		Women		Men	Women
	n	%	n	%	%	%
BMI						
Healthy Weight	367	37.4	508	58.9	38.9	65.0
Overweight[b]	450	45.8	239	24.0	43.7	22.6
Obese[c]	165	16.8	144	14.4	17.4	12.4
Waist Circumference						
Healthy Weight	702	71.4	658	68.7	59.4	63.3
Overweight[d]	168	17.1	167	16.8	26.6	19.6
Obese[e]	112	11.5	172	14.4	14.0	17.2

[a] Healthy weight includes underweight (BMI<17.5kg/m^2) (n=33)
[b] Overweight defined as a BMI of 25.0-29.9kg/m^2
[c] Overweight defined as a waist circumference of 94.0-101.9cm in men & 80.0-87.9cm in women
[d] Obesity defined as a BMI of ≥30.0 kg/m^2
[e] Obesity defined as a waist circumference of ≥102.0 cm in men & ≥88.0 cm in women

4.7 The Study Factors: Physical Activity & Cardiorespiratory Fitness

The following section describes the physical activity, sedentary behaviours and cardiorespiratory fitness of young Australian adults who participated in the CDAH follow-up study.

4.7.1 Objectively Measured Physical Activity

There was no significant difference in average daily steps between men and women overall or at any age (Table 37). Average daily steps were not significantly associated with age in either men (p=0.44) or women (p=0.33). Average daily steps observed was similar to a workplace sample of Australian adults who recorded steps for seven days using Yamax Digiwalkers, where 18-29 year olds recorded on average 9,236 and 30-44 year olds recorded on average of 8,912 (Miller, Brown et al. 2006). In a US study in adults of a similar age (18-39 years) using the same pedometer as used in the current study, the Yamax SW-200, an average of 6,782-8,124 steps per day were recorded, less than that recorded by participants in the current study (Wyatt, Peters et al. 2005). Daily steps in the current study were lower than that observed in a Swiss population-based study of adults of a similar age (25-34 years), which on average saw men taking 11,900 steps per day and women taking 9,300 steps per day as measured by a PEDOBOY pedometer (Sequeira, Rickenbach et al. 1995). However, the pedometer used in the Swiss study was mechanically different from more modern pedometers, which is likely to explain the differences observed.

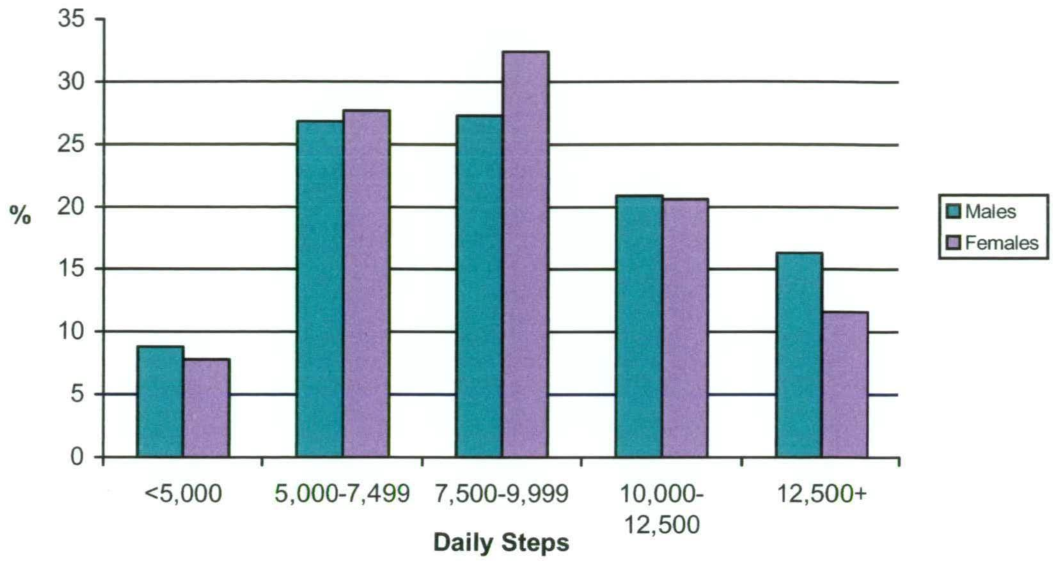
Table 37: Average daily steps in the CDAH follow-up study, by sex & age

Age (years)	Men		Women		p[a]
	n	Mean (SD)	n	Mean (SD)	
26-27	101	9,002.1 (3,384.1)	138	8,564.3 (2,732.0)	0.30
28-29	168	9,467.8 (3,814.0)	205	8,946.4 (3,078.1)	0.39
30-31	218	8,805.2 (3,224.3)	231	9,005.1 (3,125.8)	0.36[b]
32-33	217	8,727.4 (3,233.2)	216	8,713.6 (2,981.6)	0.06
34+	176	9,451.6 (3,471.9)	190	9,063.7 (3,349.0)	0.76
Overall	880	9,205.0 (3605.0)	980	8877.9 (3076.2)	0.19[b]

[a] p-values derived from Kruskal-Wallis test
[b] p-values derived from one-way ANOVA

The proportion of participants falling into each of the five public health categories for physical activity defined by Tudor-Locke (2004) are presented in Figure 20. More than 60% of participants did not achieve an average of 10,000 steps per day. The remaining proportion of participants achieved more than 10,000 steps per day and were classified as active or highly active.

Figure 20: Classification of physical activity in adults based on preliminary public health indices defined by Tudor-Locke (Tudor-Locke and Bassett 2004) in the CDAH follow-up, by sex



4.7.2 Self-Reported Physical Activity & Sedentary Behaviours

Nearly all subjects reported participating in some form of physical activity during the previous week (Table 38). Men reported more time and energy expenditure in leisure, commuting and occupational physical activity while women reported more time in household physical activity.

Table 38: Weekly self-reported physical activity by domain of activity in young Australian adults in the CDAH follow-up study, by sex

Domain of PA (units)	Sex	Participation in this Domain % (n/N)	Reported Minutes/METs		p[a]
			Median	(IQR)	
LTPA (mins)	M	73.1 (741/1,014)	190	(90, 360)	<0.01
	F	74.5 (875/1,174)	180	(90, 300)	
LTPA (METs)	M	73.1 (741/1,014)	1,059	(417, 2,034)	<0.01
	F	74.5 (875/1,174)	739	(372, 1,512)	
Commuting (mins)	M	59.8 (606/1,014)	120	(60, 280)	0.05
	F	67.5 (793/1,174)	120	(60, 210)	
Commuting (METs)	M	59.8 (606/1,014)	462	(198, 1,011)	<0.01
	F	67.5 (793/1,174)	396	(198, 714)	
Work PA (mins)	M	66.0 (669/1,014)	1,170	(240, 3,000)	<0.01
	F	46.2 (542/1,174)	480	(120, 1,500)	
Work PA (METs)	M	66.0 (669/1,014)	5,196	(990, 15,435)	<0.01
	F	46.2 (542/1,174)	2,029	(452, 6,594)	
Household (mins)	M	82.9 (841/1,014)	230	(90, 480)	<0.01
	F	91.2 (1,071/1,174)	300	(120, 720)	
Household (METs)	M	82.9 (841/1,014)	900	(360, 1,980)	<0.05
	F	91.2 (1,071/1,174)	1,000	(360, 2,520)	

PA: physical activity; LTPA: leisure time physical activity; METs: metabolic equivalents; IQR: inter-quartile range
[a] p-value derived from Kruskal-Wallis test for comparison between men and women

Men reported more time spent in total walking and vigorous physical activity and more time and energy spent in total physical activity than women (Table 39). There was no significant difference between reported time spent in moderate physical activity by men and women.

Table 39: Intensity of weekly physical activity reported by young Australian adults in the CDAH follow-up study, by sex

Physical Activity	Sex	Participation in this Domain % (n/N)	Reported Minutes/METs		p[a]
			Median	(IQR)	
Walking (mins)	M	87.1 (883/1,014)	300	(120, 870)	<0.01
	F	89.5 (1,051/1,174)	210	(100, 480)	
Moderate PA (mins)	M	92.0 (933/1,014)	410	(140, 1,080)	0.75
	F	94.5 (1,109/1,174)	390	(150, 960)	
Vigorous PA (mins)	M	80.2 (813/1,014)	360	(140, 960)	<0.01
	F	59.4 (697/1,174)	165	(60, 360)	
Total PA (mins)	M	98.9 (1,003/1,014)	1,060	(450, 2,850)	<0.01
	F	98.6 (1,157/1,174)	780	(380, 1,725)	
Total PA (METs)	M	98.9 (1,003/1,014)	4,920	(2,118, 13,281)	<0.01
	F	98.6 (1,157/1,174)	3,102	(1,500, 6,630)	

PA: physical activity; LTPA: leisure time physical activity; METs: metabolic equivalents; IQR: inter-quartile range
[a] p-value derived from Kruskal-Wallis test for comparison between men and women

Table 40 provides a description of self-reported time spent watching television, using computers and sitting in the previous week. Only 2% (n=34) of participants reported not watching television, while 13.1% (n=211) reported not using computers. Men reported spending significantly more time in all sedentary behaviours than women.

Table 40: Weekly time (hours) in TV viewing, computer usage & sitting in the past week by adults in the CDAH follow-up study, by sex

Sedentary Behaviour	Sex	Participation in this Domain % (n/N)	Reported Minutes Median	(IQR)	p[a]
TV Viewing (weekdays)	M	96.4 (977/1,014)	8	(4, 12)	<0.01
	F	96.3 (1,130/1,174)	7	(3, 10)	
TV Viewing (weekends)	M	94.9 (962/1,014)	5	(3, 8)	<0.01
	F	92.6 (1,087/1,174)	4	(2, 6)	
TV Viewing (total)	M	97.6 (990/1,014)	13	(7, 20)	<0.01
	F	97.2 (1,141/1,174)	10.5	(6, 16)	
Computer Use (weekdays)	M	84.3 (855/1,014)	10	(3, 30)	<0.01
	F	89.9 (1,005/1,174)	8	(2, 30)	
Computer Use (weekends)	M	69.0 (700/1,014)	2	(1, 4.5)	<0.01
	F	54.5 (640/1,174)	1	(1, 2.5)	
Computer Use (total)	M	87.3 (885/1,014)	13	(5, 34)	<0.01
	F	87.1 (1,023/1,174)	9	(2.5, 30)	
Sitting (weekdays)	M	97.8 (992/1,014)	30	(15, 45)	0.05
	F	96.8 (1,137/1,174)	25	(15, 40)	
Sitting (weekends)	M	98.0 (994/1,014)	8	(6, 12)	<0.01
	F	96.6 (1,134/1,174)	8	(5, 12)	
Sitting (total)	M	98.8 (1,002/1,014)	38	(22, 56)	<0.05
	F	97.5 (1,145/1,174)	35	(21.5, 52)	

[a] p-value derived from Kruskal-Wallis test for differences between men and women; IQR: inter-quartile range

The proportions of participants who were categorised as low, moderate, high or very high active using the IPAQ classification system are presented in Table 41 (see section 4.2.3 for further detail about classification). Approximately 10% of participants were deemed low active, a quarter of men and more than a third of women were moderately active, a quarter of men and just less than a third of women were high active, and more than a third of men and one fifth of women were very high active.

Table 41: Proportion of participants categorised as low, moderate, high or very high active using the IPAQ classification system in the CDAH follow-up study, by sex

IPAQ Classification of Physical Activity	Men (N=1,087)		Women (N=1,284)	
	n	%	n	%
Low	104	10.3	133	10.8
Moderate	260	25.7	474	38.4
High	266	26.3	373	30.2
Very High	383	37.8	256	20.7

4.7.3 Cardiorespiratory Fitness

1,724 participants completed a PWC_{170} cycle ergometer test as an estimate of cardiorespiratory fitness test (Table 42). Although differences were modest, men had significantly higher values than women at all ages except 32-33 years. In addition, although marginal, values significantly increased with age in both men and women ($p<0.01$ and $p=0.07$, respectively).

Table 42: Mean (standard deviation) watts per kilogram of lean body mass (W/kglbm) derived from the PWC_{170} cycle ergometer test in young Australian adults in the CDAH follow-up study, by sex

Age (years)	Men		Women		p
	n	Mean (SD)	n	Mean (SD)	
26-27	96	3.0 (0.7)	123	2.8 (0.7)	<0.01
28-29	182	3.1 (0.6)	187	2.9 (0.7)	<0.01
30-31	219	3.1 (0.6)	198	2.9 (0.7)	<0.01
32-33	207	3.0 (0.6)	174	2.9 (0.6)	0.38
34+	179	3.2 (0.7)	159	3.0 (0.7)	<0.05
Overall	883	3.2 (0.6)	841	2.9 (0.7)	<0.01

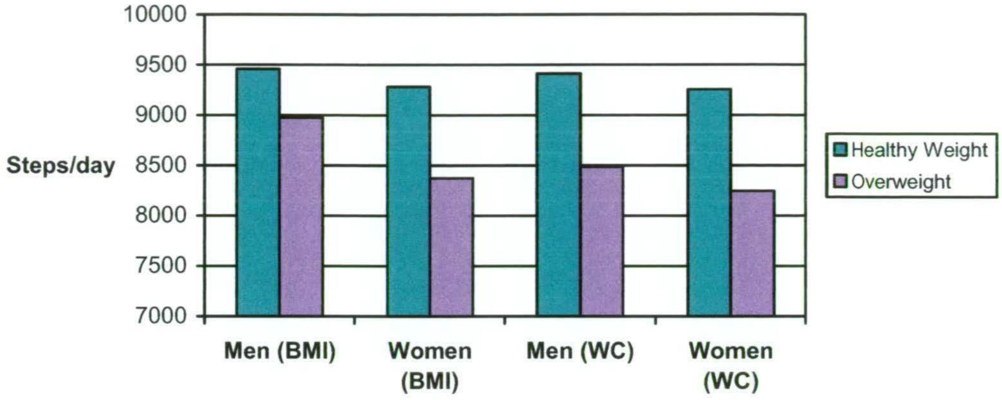
4.8 Bivariable Analyses: Predictors of a Healthy Weight

The following section presents bivariable and multivariable cross-sectional analyses of data collected as part of the CDAH follow-up study. It firstly explores bivariable associations between healthy weight and physical activity, as well as bivariable associations between healthy weight and sociodemographic factors and cardiorespiratory fitness.

4.8.1 Daily Steps & Healthy Weight

Daily steps were weakly correlated with BMI in females (r=–0.13, $p<0.01$), but not males (r=–0.07, $p=0.06$), and was weakly correlated with waist circumference in both females (r=–0.15, $p<0.01$) and males (r=–0.08, $p<0.05$). Healthy weight men and women recorded higher average daily step counts than overweight participants (Figure 21) (see Appendix 14b, Table 18 for mean values and standard deviations). These differences were significant in women ($p<0.01$) and men ($p=0.06$) when using BMI to define healthy weight. When using waist circumference to define healthy weight, similar results were seen for women, but differences were more marked in men. When examined separately by age category, there remained no difference between daily steps in healthy weight and overweight men, but for women there were significant differences at most ages except 26-27 years and 34+ years (data not shown). These same results were observed irrespective of the definition of healthy weight.

Figure 21: Average daily steps in healthy weight & overweight young Australian adults in the CDAH follow-up study using BMI or waist circumference (WC) to define weight status, by sex



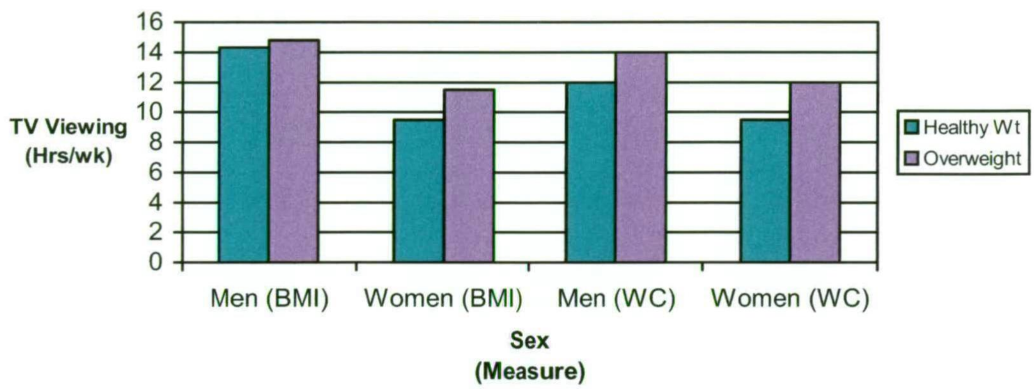
4.8.2 Self-Reported Physical Activity & Sedentary Behaviour & Healthy Weight

Weekly self-reported physical activity was not correlated with BMI or waist circumference in either men (r=0.04, p=0.26 and r=0.03, p=0.32, respectively) or women (r=0.05, p=0.08 and r=0.05, p=0.12, respectively). Overweight (defined using BMI) men reported higher median values than healthy weight men for time and energy spent in leisure, household/yard and total physical activity, although this difference was not significant (Appendix 14b, Table 19). While this seems counter-intuitive, it is plausible that overweight men were trying to reduce their weight by participating in more physical activity. Healthy weight men reported higher median values for time spent in active commuting, but these differences were not statistically significant. There was little difference in median values reported by overweight and healthy weight women, except for commuting activity, which was higher amongst healthy weight women. In contrast, when waist circumference was used to define healthy weight, healthy weight men reported significantly more time and energy spent in leisure activity than overweight men (Appendix 14b, Table 20). The differences in time and energy spent in household and yard physical activity became statistically significant in both men and women, with overweight participants reporting more time in these activities.

When examining the intensity of physical activity, there was no significant difference between healthy weight and overweight men (using either BMI or waist circumference to define weight status), although overweight men tended to report more time in walking, moderate, vigorous and total physical activity (Appendix 14b, Tables 21 & 22). There were no significant differences between median values reported by healthy weight and overweight women, with healthy weight women reporting more walking and overweight women reporting more moderate and total physical activity, although the differences were modest. There was no difference in median values for vigorous activity reported by healthy weight and overweight women.
When using BMI to define weight status, healthy weight women reported significantly less time in weekly television viewing than overweight women (p<0.01) (Figure 22). While overweight

men reported slightly more television viewing than healthy weight men, this difference was not significant. When waist circumference was used to define weight status, the differences in time spent in television viewing between healthy weight and overweight men became statistically significant, with healthy weight men reporting less time in television viewing than overweight men. Healthy weight and overweight men tended to report similar median values for computer use and sitting regardless of the measure used to define weight status, while overweight women (defined using BMI) tended to report higher median values than healthy weight women (Appendix 14b, Tables 23 & 24).

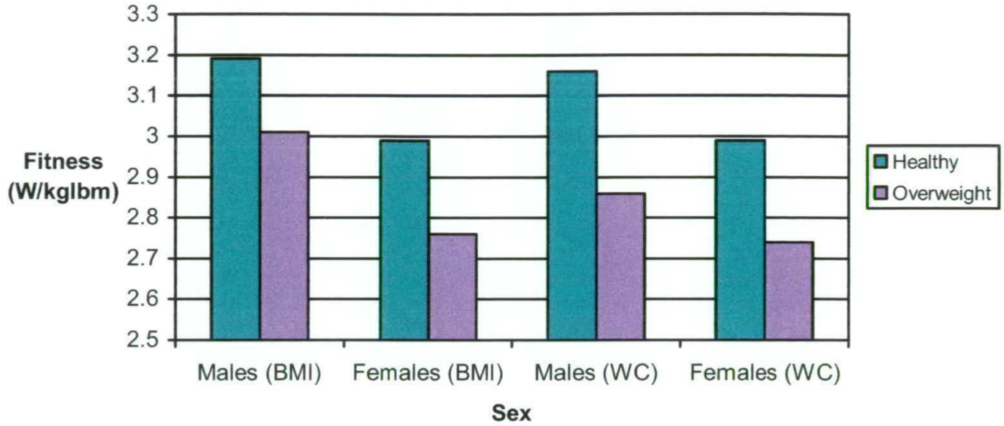
Figure 22: Average television viewing (hours/week) in healthy weight & overweight young Australian adults in the CDAH follow-up study using BMI & waist circumference (WC) to define weights status, by sex



4.8.3 Cardiorespiratory Fitness & Healthy Weight

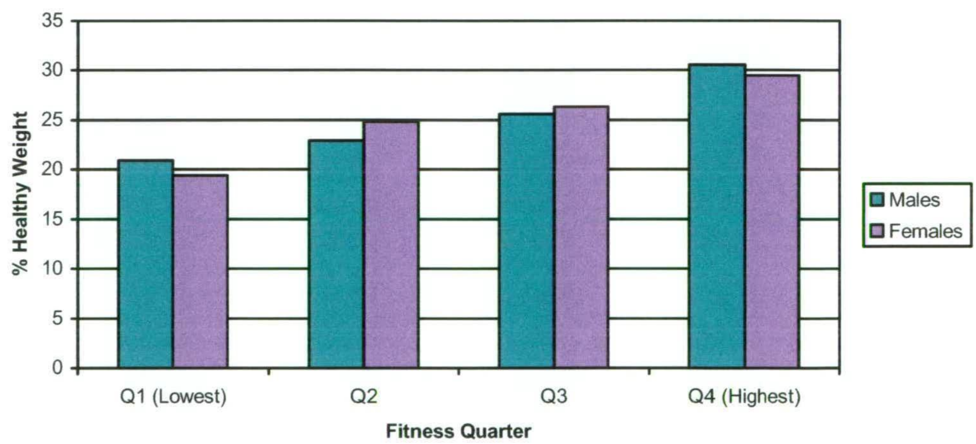
Cardiorespiratory fitness was inversely correlated with BMI and waist circumference in both men (r=–0.18, p<0.01 and r=–0.21, p<0.01, respectively) and women (r=–0.18, p<0.01 and r=–0.20, p<0.01, respectively). Healthy weight men and women had significantly greater levels of cardiorespiratory fitness than overweight men (p<0.01) and women (p<0.01) (Figures 23). Findings were similar when using waist circumference to define healthy weight, although the differences were again more marked for men (p<0.01 in both men and women).

Figure 23: Average cardiorespiratory fitness (W/kglbm) as measured by PWC_{170} cycle ergometer test in healthy weight & overweight young Australian adults in the CDAH follow-up study using BMI & waist circumference (WC) to define weight status, by sex



Additionally, the proportion of healthy weight men and women increased across increasing quarters of cardiorespiratory fitness (Figure 24).

Figure 24: Proportion of healthy weight Australian adults in the CDAH follow-up study by quarter of cardiorespiratory fitness as measured by PWC_{170} cycle ergometer test, by sex



4.8.4 Sociodemographic Characteristics & Healthy Weight

An examination of the relationship between healthy weight and a number of potential confounders is presented in Table 43. Women who were not in the labour force had a lower prevalence of healthy weight, compared with those in the highest occupation level. A large proportion of these women had an occupational status of home duties, therefore it is likely that many have had children recently, possibly explaining the lower prevalence of healthy weight. In contrast, men who were not in the labour forces had an increased prevalence of healthy weight. In addition, men in blue collar occupations had a lower prevalence of healthy weight than men in the highest occupation level. Both men and women who had completed a diploma/vocational training or school only had a lower prevalence of healthy weight than those who had a university or higher degree. There was little difference in weight status according to marital status, except that men in de facto relationships had a lower prevalence of healthy weight than those who were single. No differences were observed for smoking in either men or women, while women with three or more children were least likely to be a healthy weight. While country of birth was not associated with healthy weight in women, men born outside Australia had a higher prevalence of healthy weight than men born in Australia.

Using waist circumference to define healthy weight provided similar results (Appendix 14b, Table 25), although there was an elevated prevalence of healthy weight in women who were born outside Australia.

Table 43: Ratios of prevalence of healthy weight & sociodemographic characteristics in the CDAH follow-up study, by sex

Sociodemographic Characteristic	Men				Women			
	BMI<25kg/m²		PR	(95% CI)	BMI<25kg/m²		PR	(95% CI)
	%	(n/N)			%	(n/N)		
Occupation Level								
Manager/professional	38.9	(213/547)	1.0	(ref)	62.4	(319/511)	1.0	(ref)
White collar	48.0	(35/73)	1.23	(0.95-1.60)	60.4	(172/285)	0.97	(0.86-1.09)
Blue collar	31.6	(93/294)	**0.81**	**(0.67-0.99)**	60.8	(31/51)	0.97	(0.77-1.23)
Not in labour force	58.1	(18/31)	**1.49**	**(1.09-2.05)**	48.2	(79/164)	**0.77**	**(0.65-0.92)**
Education								
University/higher degree	46.3	(169/365)	1.0	(ref)	67.7	(314/464)	1.0	(ref)
Diploma/vocational	29.5	(100/339)	**0.64**	**(0.52-0.78)**	51.0	(132/259)	**0.75**	**(0.66-0.86)**
School only	37.5	(88/235)	**0.81**	**(0.66-0.99)**	53.5	(152/284)	**0.79**	**(0.70-0.90)**
Marital Status[a]								
Single	46.3	(131/283)	1.0	(ref)	58.2	(153/263)	1.0	(ref)
De Facto	32.6	(160/491)	**0.70**	**(0.59-0.84)**	58.2	(319/548)	1.00	(0.88-1.13)
Married	37.8	(56/148)	0.82	(0.64-1.04)	65.9	(108/164)	1.13	(0.97-1.32)
Separated/Divorced	58.8	(56/148)	1.27	(0.84-1.93)	52.5	(21/40)	0.90	(0.66-1.23)
Smoking								
Non-Smoker	38.7	(213/550)	1.0	(ref)	59.4	(335/564)	1.0	(ref)
Occasional Smoker	46.2	(42/550)	1.19	(0.92-1.55)	62.5	(27/45)	1.05	(0.87-1.27)
Daily Smoker	39.6	(63/159)	1.02	(0.82-1.27)	56.1	(88/156)	0.95	(0.81-1.11)
Parity								
No children	-	-	-	-	63.8	(342/536)	1.0	(ref)
1 child	-	-	-	-	59.1	(101/171)	0.93	(0.80-1.06)
2 children	-	-	-	-	56.3	(139/247)	0.88	(0.78-1.00)
3+ children	-	-	-	-	45.5	(51/112)	**0.71**	**(0.58-0.88)**
Country of Birth[b]								
Australia	34.7	(267/769)	1.0	(ref)	58.7	(458/780)	1.0	(ref)
Outside Australia	48.3	(29/60)	**1.39**	**(1.05-1.84)**	57.8	(26/45)	0.98	(0.76-1.27)

PR: unadjusted prevalence ratios
[a] One female participant was a widow and was not included in this analyses
[b] Country of birth data only available for participants aged 9-15 years in the ASHFS 1985

4.9 Multivariable Analysis: Healthy Weight, Physical Activity & Fitness

A log binominal model was used to explore multivariable associations between healthy weight and physical activity and sedentary behaviour in men (Table 44). There was no significant difference between men in the lowest category of daily steps (<5,000) compared with men in any other category (>5,000), although a trend for higher prevalence of healthy weight was observed across increasing steps categories. There was little evidence of an association between healthy weight and self-reported physical activity. There was no relationship between television viewing, time spent sitting or computer use and the prevalence of healthy weight in men, and no significant trends were observed. Adjusting for sociodemographic variables made little difference to the associations, although in some instances the strength of the associations increased but did not reach statistical significance.

However, when waist circumference was used to define healthy weight, different results were observed for associations with daily steps (Table 45). Men who recorded higher average daily step counts had a higher prevalence of healthy weight than men achieving the least steps (<5,000), a finding that was statistically significant for those achieving 7,500 or more steps per day.

Table 44: Ratios of prevalence of healthy weight (defined using BMI) for men in the CDAH follow-up study, by average physical activity & sedentary behaviour levels

Physical Activity (PA) or Sedentary Behaviour	**BMI<25kg/m²** %	**(n/N)**	**PR[a]**	**(95% CI)**	**Adj. PR[b]**	**(95% CI)**
Daily Steps[c]						
<5,000	36.1	(26/72)	1.0	(ref)	1.0	(ref)
5,000-7,499	37.2	(87/234)	1.03	(0.73-1.46)	1.03	(0.67-1.57)
7,500-9,999	41.2	(96/233)	1.14	(0.81-1.61)	1.33	(0.89-1.99)
10,000-12,499	37.5	(66/176)	1.04	(0.72-1.49)	1.04	(0.67-1.60)
12,500+	46.4	(64/138)	1.28	(0.50-1.83)	1.44	(0.94-2.22)
				P_{trend} = 0.14		P_{trend} = 0.07
Self-Reported PA (IPAQ[d])						
Low	36.7	(36/98)	1.0	(ref)	1.0	(ref)
Moderate	40.0	(100/250)	1.09	(0.81-1.47)	1.23	(0.84-1.81)
High	42.5	(110/259)	1.16	(0.86-1.55)	1.24	(0.85-1.83)
Very High	34.3	(129/376)	0.93	(0.70-1.25)	1.17	(0.78-1.76)
				P_{trend} =0.29		P_{trend} = 0.79
TV Viewing						
<1 hr/day	40.5	(92/227)	1.0	(ref)	1.0	(ref)
1-2 hrs/day	39.0	(114/292)	0.96	(0.78-1.19)	0.93	(0.71-1.21)
2-3 hrs/day	35.6	(89/250)	0.88	(0.70-1.10)	0.97	(0.75-1.27)
3+ hrs/day	37.1	(79/213)	0.92	(0.72-1.16)	0.94	(0.70-1.26)
				P_{trend} = 0.33		P_{trend} = 0.75
Sitting						
<20 hrs/week	36.6	(72/197)	1.0	(ref)	1.0	(ref)
20-40 hrs/week	37.8	(125/331)	1.03	(0.82-1.30)	0.90	(0.73-1.12)
40-60 hrs/week	41.2	(100/243)	1.13	(0.89-1.43)	1.01	(0.82-1.26)
60+ hrs/week	36.5	(77/211)	1.00	(0.77-1.29)	0.98	(0.76-1.26)
				P_{trend} = 0.81		P_{trend} = 0.90
Computer Use						
<10 hrs/week	36.8	(179/487)	1.0	(ref)	1.0	(ref)
10-20 hrs/week	37.2	(55/148)	1.01	(0.80-1.28)	0.90	(0.67-1.20)
20-30 hrs/week	40.7	(33/81)	1.11	(0.83-1.48)	1.07	(0.77-1.49)
30+ hrs/week	40.2	(107/266)	1.09	(0.91-1.32)	0.95	(0.74-1.22)
				P_{trend} = 0.31		P_{trend} = 0.89

[a] PR: unadjusted prevalence ratios
[b] Adj. PR: prevalence ratios adjusted for age at baseline, country of birth, current occupation, highest level of education & marital status
[c] Average daily steps categorised according to public health cutpoints (Tudor-Locke and Bassett 2004)
[d] Minutes of self-reported physical activity categorised according to IPAQ-L scoring protocol

Table 45: Ratios of prevalence of healthy weight (defined using waist circumference) for men in the CDAH follow-up study by average physical activity & sedentary behaviour levels

Physical Activity (PA) or Sedentary Behaviour	WC<94cm %	(n/N)	PR[a]	(95% CI)	Adj. PR[b]	(95% CI)
Daily Steps[c]						
<5,000	61.2	(41/67)	1.0	(ref)	1.0	(ref)
5,000-7,499	68.6	(153/223)	1.12	(0.91-1.38)	1.20	(0.95-1.51)
7,500-9,999	73.6	(159/216)	1.20	(0.98-1.48)	**1.33**	**(1.05-1.67)**
10,000-12,499	73.5	(122/166)	1.20	(0.97-1.48)	**1.37**	**(1.08-1.74)**
12,500+	82.7	(105/127)	**1.35**	**(1.10-1.66)**	**1.60**	**(1.27-2.02)**
				$P_{trend} < 0.01$		$P_{trend} < 0.01$
Self-Reported PA (IPAQ[d]*)*						
Low	67.1	(108/161)	1.0	(ref)	1.0	(ref)
Moderate	70.8	(167/236)	1.05	(0.92-1.21)	1.11	(0.91-1.35)
High	78.4	(192/245)	1.17	(1.03-1.33)	1.20	(0.99-1.45)
Very High	68.9	(221/321)	1.03	(0.90-1.17)	1.16	(0.95-1.42)
				P_{trend}=0.63		P_{trend} = 0.05
TV Viewing						
<1 hr/day	75.0	(153/204)	1.0	(ref)	1.0	(ref)
1-2 hrs/day	75.5	(203/269)	1.01	(0.91-1.12)	0.97	(0.87-1.08)
2-3 hrs/day	68.7	(156/227)	0.92	(0.81-1.03)	0.98	(0.88-1.10)
3+ hrs/day	66.8	(129/193)	0.89	(0.78-1.01)	0.89	(0.77-1.03)
				P_{trend} = <0.01		P_{trend} = 0.05
Sitting						
<20 hrs/week	71.3	(124/174)	1.0	(ref)	1.0	(ref)
20-40 hrs/week	73.2	(213/291)	1.03	(0.91-1.15)	1.00	(0.91-1.10)
40-60 hrs/week	72.6	(167/230)	1.02	(0.90-1.15)	1.00	(0.90-1.11)
60+ hrs/week	69.2	(137/198)	0.97	(0.85-1.11)	0.90	(0.80-1.03)
				P_{trend} = 0.60		P_{trend} = 0.13
Computer Use						
<10 hrs/week	69.7	(299/429)	1.0	(ref)	1.0	(ref)
10-20 hrs/week	68.1	(96/141)	0.98	(0.86-1.11)	1.00	(0.89-1.14)
20-30 hrs/week	75.3	(55/73)	1.08	(0.93-1.25)	1.03	(0.89-1.20)
30+ hrs/week	76.4	(191/250)	1.10	(1.00-1.20)	1.00	(0.89-1.11)
				P_{trend} = 0.05		P_{trend} = 0.42

[a] PR: unadjusted prevalence ratios
[b] Adj. PR: prevalence ratios adjusted for age at baseline, occupation, education, marital status & country of birth
[c] Average daily steps categorised according to public health cutpoints defined by Tudor-Locke et al (Tudor-Locke and Bassett 2004)
[d] Minutes of self-reported physical activity categorised according to IPAQ-L scoring protocol

For women, achieving more than 5,000 steps per day was associated with a higher prevalence of healthy weight compared with those who achieved less than 5,000 steps per day (Table 46). A significant trend across increasing step categories was observed. Based on self-reported physical activity, women in the high active category had a marginally elevated prevalence of healthy weight compared with those deemed inactive, but this effect was not seen for women in the very high active category, and no significant trends were observed across increasing categories of activity. There was a significant trend for decreasing prevalence of healthy weight with increased television viewing time. Women watching three or more hours of television per day had a significantly lower prevalence of a healthy weight than those watching the least amount of television. After adjusting for sociodemographic variables, a similar trend was seen for time spent sitting and computer usage, with the most sedentary women having the lowest prevalence of healthy weight, and a significant trend became apparent.

Table 46: Ratios of prevalence of healthy weight for women in the CDAH follow-up study by average physical activity & sedentary behaviour levels

Physical Activity (PA) or Sedentary Behaviour	BMI<25kg/m^2 %	(n/N)	PR[a]	(95% CI)	Adj. PR[b]	(95% CI)
Daily Steps[a]						
<5,000	40.4	(19/47)	1.0	(ref)	1.0	(ref)
5,000-7,499	54.5	(103/189)	**1.47**	**(1.06-2.04)**	**1.38**	**(1.00-1.91)**
7,500-9,999	56.4	(127/225)	**1.52**	**(1.10-2.09)**	**1.42**	**(1.03-1.96)**
10,000-12,499	64.8	(92/142)	**1.66**	**(1.20-2.30)**	**1.56**	**(1.13-2.16)**
12,500+	77.8	(63/81)	**1.95**	**(1.41-2.70)**	**1.79**	**(1.29-2.48)**
				P_{trend} < 0.01		P_{trend} < 0.01
Self-Reported PA[b]						
Low	56.3	(45/80)	1.0	(ref)	1.0	(ref)
Moderate	58.3	(162/278)	1.04	(0.83-1.29)	1.19	(0.97-1.46)
High	65.6	(149/227)	1.17	(0.94-1.45)	**1.28**	**(1.04-1.57)**
Very High	51.2	(86/168)	0.91	(0.71-1.16)	1.11	(0.88-1.39)
				P_{trend} =0.56		P_{trend} = 0.40
TV Viewing						
<1 hr/day	65.2	(137/210)	1.0	(ref)	1.0	(ref)
1-2 hrs/day	60.3	(155/257)	0.92	(0.80-1.06)	0.93	(0.83-1.04)
2-3 hrs/day	60.1	(95/158)	0.92	(0.78-1.08)	0.91	(0.79-1.05)
3+ hrs/day	42.1	(48/114)	**0.65**	**(0.51-0.82)**	**0.67**	**(0.55-0.82)**
				P_{trend} <0.01		P_{trend} < 0.01
Sitting						
<20 hrs/week	63.0	(92/146)	1.0	(ref)	1.0	(ref)
20-40 hrs/week	56.2	(159/283)	0.89	(0.76-1.05)	1.04	(0.94-1.16)
40-60 hrs/week	57.3	(106/185)	0.91	(0.76-1.08)	0.95	(0.83-1.08)
60+ hrs/week	58.0	(69/119)	0.92	(0.76-1.12)	**0.70**	**(0.58-0.84)**
				P_{trend} = 0.49		P_{trend} < 0.01
Computer Use						
<10 hrs/week	59.2	(200/338)	1.0	(ref)	1.0	(ref)
10-20 hrs/week	59.1	(55/93)	1.00	(0.83-1.21)	0.99	(0.85-1.16)
20-30 hrs/week	55.4	(36/65)	0.94	(0.74-1.18)	0.85	(0.69-1.04)
30+ hrs/week	56.3	(94/167)	0.95	(0.81-1.12)	**0.86**	**(0.76-0.98)**
				P_{trend} = 0.48		P_{trend} < 0.05

[a] PR: unadjusted prevalence ratios
[b] Adj. PR: prevalence ratios adjusted for age, occupation, education & parity
[c] Average daily steps categorised according to public health cutpoints (Tudor-Locke and Bassett 2004)
[d] Minutes of self-reported physical activity categorised according to IPAQ-L scoring protocol

Using waist circumference to define healthy weight yielded similar results, although the association being healthy weight and computer usage was no longer evident (Table 47).

Table 47: Ratios of prevalence (PR) of healthy weight (defined using waist circumference) for women in the CDAH follow-up study categorised by their average physical activity & sedentary behaviour levels

	WC<80cm %	(n/N)	PR[a]	(95% CI)	Adj. PR[b]	(95% CI)
Daily Steps[c]						
<5,000	39.3	(22/56)	1.0		1.0	
5,000-7,499	64.8	(149/230)	**1.65**	**(1.17-2.32)**	**1.57**	**(1.12-2.19)**
7,500-9,999	64.3	(169/263)	**1.64**	**(1.17-2.30)**	**1.51**	**(1.08-2.10)**
10,000-12,499	73.2	(131/179)	**1.86**	**(1.32-2.61)**	**1.71**	**(1.23-2.38)**
12,500+	76.6	(72/94)	**1.95**	**(1.38-2.75)**	**1.64**	**(1.16-2.30)**
				P_{trend} < 0.01		P_{trend} < 0.01
Self-Reported PA[d]						
Inactive	65.9	(91/138)	1.0		1.0	
Minimally Active	64.5	(238/369)	0.98	(0.85-1.13)	1.01	(0.86-1.18)
Suff. Active (L)	70.0	(201/287)	1.06	(0.92-1.22)	1.06	(0.90-1.25)
Suff. Active (U)	63.1	(125/198)	0.96	(0.82-1.12)	1.00	(0.84-1.19)
				P_{trend} 0.99		P_{trend} = 0.49
TV Viewing						
<1 hr/day	73.4	(218/297)	1.0		1.0	
1-2 hrs/day	67.4	(221/328)	0.92	(0.83-1.02)	0.92	(0.83-1.00)
2-3 hrs/day	63.3	(119/188)	**0.86**	**(0.76-0.98)**	0.84	(0.79-1.00)
3+ hrs/day	50.7	(73/144)	**0.69**	**(0.58-0.82)**	**0.70**	**(0.58-0.83)**
				P_{trend} <0.01		P_{trend} < 0.01
Sitting						
<20 hrs/week	66.5	(141/212)	1.0		1.0	
20-40 hrs/week	66.2	(221/334)	0.99	(0.83-1.12)	1.06	(0.97-1.16)
40-60 hrs/week	66.3	(167/252)	1.00	(0.87-1.13)	0.94	(0.84-1.05)
60+ hrs/week	64.2	(102/159)	0.96	(0.83-1.12)	**0.73**	**(0.62-0.87)**
				P_{trend} = 0.68		P_{trend} < 0.01
Computer Use						
<10 hrs/week	65.8	(348/529)	1.0		1.0	
10-20 hrs/week	62.6	(72/115)	0.95	(0.82-1.11)	0.94	(0.82-1.08)
20-30 hrs/week	67.1	(51/76)	1.02	(0.86-1.21)	0.92	(0.77-1.09)
30+ hrs/week	67.5	(160/237)	1.03	(0.92-1.14)	0.92	(0.82-1.03)
				P_{trend} = 0.62		P_{trend} = 0.05

[a] PR: unadjusted prevalence ratios
[b] Adj. PR: prevalence ratios adjusted for age at baseline, occupation, education & parity
[c] Average daily steps categorised according to public health cutpoints defined by Tudor-Locke et al (Tudor-Locke and Bassett 2004)
[d] Minutes of self-reported physical activity categorised according to IPAQ-L scoring protocol

When using BMI to define healthy weight, those men in the highest quarter of cardiorespiratory fitness and those women in the top two quarters of cardiorespiratory fitness had a higher prevalence of healthy weight, compared with those in the bottom quarter of cardiorespiratory fitness (Table 48). However, when adjusted for sociodemographic factors, the effects were attenuated and in men became non-significant. When using waist circumference to define healthy weight, men in the top two quarters of cardiorespiratory fitness had a greater prevalence of healthy weight, while for women, similar but weaker associations were observed.

Table 48: Ratios of prevalence of healthy weight categorised by quarters of cardiorespiratory fitness (by PWC_{170}[a]) in young Australian adults in the CDAH follow-up study using BMI & waist circumference to define weight status, by sex

Measure Used to Define Weight Status, Sex & Fitness Quarter	Healthy Weight %	(n/N)	PR[b]	(95% CI)	Adj. PR[c]	(95% CI)
BMI<25kg/m²						
Men						
Q1 (lowest)	21.2	(70/216)	1.0		1.0	
Q2	21.8	(72/213)	1.04	(0.80-1.37)	0.94	(0.69-1.29)
Q3	26.6	(88/220)	1.23	(0.96-1.59)	1.01	(0.76-1.35)
Q4 (highest)	30.5	(101/216)	**1.44**	**(1.14-1.83)**	1.25	(0.94-1.67)
				P_{trend} < 0.01		P_{trend} = 0.12
Women						
Q1 (lowest)	20.6	(104/206)	1.0		1.0	
Q2	23.6	(119/201)	1.17	(0.98-1.40)	1.14	(0.95-1.38)
Q3	26.2	(132/208)	**1.26**	**(1.06-1.49)**	**1.27**	**(1.07-1.52)**
Q4 (highest)	29.6	(149/204)	**1.45**	**(1.23-1.70)**	**1.39**	**(1.18-1.64)**
				P_{trend} < 0.01		P_{trend} < 0.01
Waist Circumference						
Men (WC<94cm)						
Q1 (lowest)	20.7	(129/216)	1.0		1.0	
Q2	22.7	(141/213)	1.11	(0.96-1.28)	1.09	(0.91-1.29)
Q3	26.7	(166/220)	**1.26**	**(1.11-1.44)**	**1.21**	**(1.03-1.43)**
Q4 (highest)	29.9	(186/216)	**1.44**	**(1.28-1.63)**	**1.37**	**(1.18-1.60)**
				P_{trend} < 0.01		P_{trend} < 0.01
Women (WC<80cm)						
Q1 (lowest)	21.7	(122/212)	1.0		1.0	
Q2	23.3	(131/206)	1.11	(0.95-1.29)	1.05	(0.90-1.23)
Q3	25.1	(141/210)	1.17	(1.00-1.35)	1.15	(1.00-1.32)
Q4 (highest)	29.9	(168/211)	**1.38**	**(1.21-1.58)**	**1.28**	**(1.11-1.47)**
				P_{trend} < 0.01		P_{trend} < 0.01

[a] PWC_{170} adjusted for lean body mass
[b] PR: unadjusted prevalence ratios
[c] Adj. PR: prevalence ratios adjusted for age at baseline, country of birth, occupation, highest level of education, marital status (men) & prevalence ratios adjusted for occupation, highest level of education & parity (women)

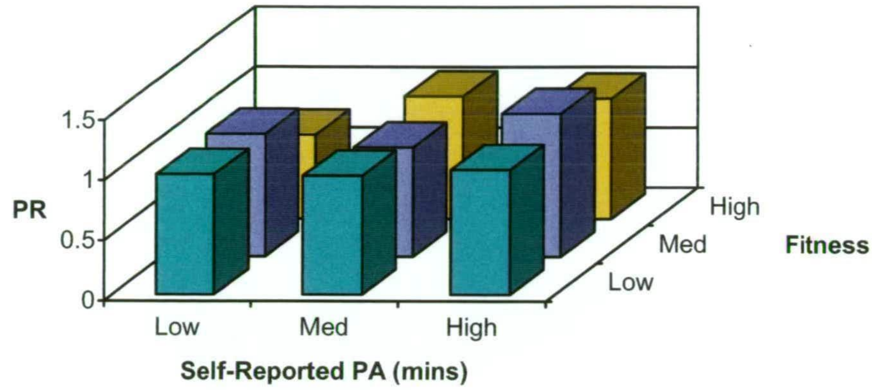
The combined effects of physical activity or sedentary behaviour and cardiorespiratory fitness on the sex-adjusted prevalence of healthy weight are presented in Figures 25, 26 and 27. Findings differed according to the measure of physical activity or sedentary behaviour (significant differences are highlighted with stars). Using a combined measure of cardiorespiratory fitness and daily steps, the medium physical activity/medium fitness (PR 1.29, 95% CI 1.01-1.66), high physical activity/medium fitness (PR 1.30, 95% CI 1.01-1.67) or high physical activity/high fitness (PR 1.39, 95% CI 1.08-1.78) groups had a significantly elevated prevalence of healthy weight compared to the "low physical activity/low fitness" reference group

(Appendix 14b, Table 26). When using waist circumference to define healthy weight, those in the low physical activity/high fitness group (PR 1.25, 95% CI 1.04-1.50), medium physical activity/medium fitness (PR 1.26, 95% CI 1.05-1.50), medium physical activity/high fitness (PR 1.26, 95% CI 1.06-1.51), high physical activity/medium fitness (PR 1.28, 95% CI 1.04-1.49) and high physical activity/high fitness (PR 1.41, 95% CI 1.19-1.66) had a greater prevalence of healthy weight than the reference group (low physical activity/low fitness) (Appendix 14b, Table 27).

Figure 25: The combined effects of daily steps & cardiorespiratory fitness and the prevalence of healthy weight in young Australian adults in the CDAH follow-up study (adjusted for gender, age, occupation, education, marital status, country of birth) (PR: prevalence ratio)

No association was noted between a combined measure of cardiorespiratory fitness and self-reported physical activity and the likelihood of being a healthy weight (Appendix 14b, Table 28). When using waist circumference to define healthy weight, the medium physical activity/high fitness group had a marginally elevated prevalence of healthy weight (PR 1.26, 95% CI 1.07-1.47) (Appendix 14b, Table 29).

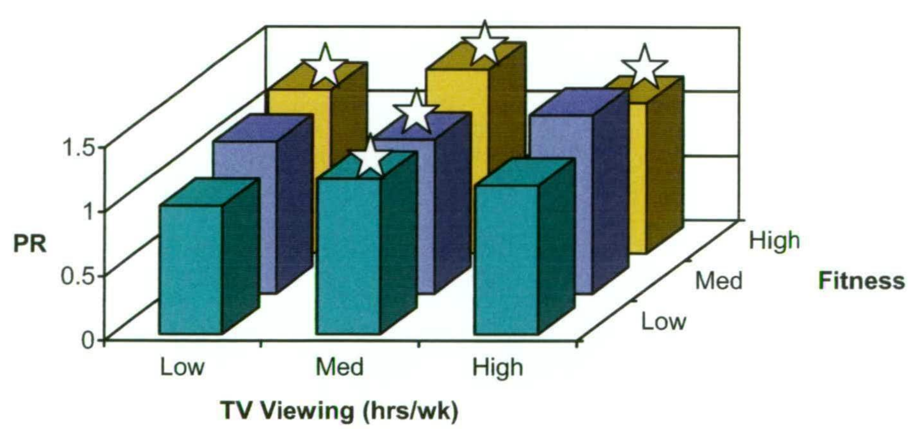
Figure 26: The combined effects of self-reported time in physical activity & cardiorespiratory fitness and the prevalence of healthy weight in young Australian adults in the CDAH follow-up study (adjusted for gender, age, occupation, education, marital status, country of birth & parity) (PR: prevalence ratio)



☆= confidence intervals do not include 1.0

Those participants with high fitness had a higher prevalence of healthy weight irrespective of their level of television viewing, as did participants who were in the middle television viewing group irrespective of their fitness (Appendix 14b, Table 30). When using waist circumference to define healthy weight, only those participants in the high fitness or medium fitness-low television viewing groups had a higher prevalence of healthy weight (Appendix 14b, Table 31)

Figure 27: The combined effects of sedentary behaviour (television viewing) & cardiorespiratory fitness and the prevalence of healthy weight in young Australian adults in the CDAH follow-up study (PR: prevalence ratio) (adjusted for gender, age, occupation, education, marital status, country of birth & parity) (PR: prevalence ratio)



☆= confidence intervals do not include 1.0

4.10 Discussion

This chapter aimed to determine whether physically active and fit adults had a higher prevalence of healthy weight than less active and less fit adults in a sample of young Australians aged 26-36 years. This is the largest study to do so using an objective measure of physical activity, pedometers. As expected and as observed in previous studies, the findings suggest that more active and fitter adults indeed demonstrated a higher prevalence of healthy weight than less active and fit adults. Additionally, higher levels of sedentary behaviour were associated with a lower prevalence of healthy weight in women. Associations were generally stronger in women than in men, supporting findings from the literature review, where associations between physical activity and adiposity were more evident in women than men. It is plausible that the physical activity measures used may better reflect the energy expended by the types of physical activities women do than the energy expended by the types of activities men do. If so, pedometers readings are likely to demonstrate stronger associations with adiposity in women while underestimating associations in men. This seems likely because pedometers better reflect the energy expenditure of ambulatory activities, such as walking, than vigorous activities or activities that involve isometric movements, such as strength training. Women participate in walking for exercise more than men, while men tend to participate in more vigorous activities than women (Australian Sports Commission 2004), so this explanation seems plausible. Alternatively, because men are more likely to participate in vigorous activities, such as contact sports, pedometers may be removed during this time and hence these higher energy expending activities may not be adequately reflected by pedometer readings.

While a number of previous studies have noted stronger associations between cardiorespiratory fitness and adiposity than between physical activity and adiposity (Lochen and Rasmussen 1992; Eaton, Lapane et al. 1995; McMurray, Ainsworth et al. 1998; Suzuki, Yamada et al. 1998; Dvorak, Tchernof et al. 2000), this was not the case in the current study. Women who achieved at least 12,500 steps per day had a 79% higher prevalence of healthy weight than those achieving less than 5,000 steps per day, while women in the highest cardiorespiratory fitness quarter had a 28-39% higher prevalence of healthy weight than those in the lowest quarter. For men, achieving at least 12,500 steps per day was associated with a 60% increase in the prevalence of healthy weight (defined using waist circumference), compared with a 37% increase for being in the highest fitness quarter. While the reasons for these findings are unknown, it is possible that the differences in the outcomes – healthy weight in the current study as opposed to overweight and obesity or continuous measures of adiposity in previous studies – are responsible.

Although some authors have suggested that cardiorespiratory fitness and physical activity may influence weight status via different mechanisms, it seems more likely that differences in the physical activity measures used in this and other studies are responsible for differences in the strength of the associations seen between adiposity and physical activity. Previous studies that used self-reported measures of physical activity all observed weaker associations with adiposity than cardiorespiratory fitness (Lochen and Rasmussen 1992; Eaton, Lapane et al. 1995; McMurray, Ainsworth et al. 1998). Similarly, two smaller studies compared objective measures of physical activity (DLW and accelerometry) to cardiorespiratory fitness, with like findings. Because of differences in sampling and objective physical activity measures used, the results from these studies are difficult to compare with the current study. For instance, one of these studies was conducted in a small sample of older adults (aged 60 years and over), while the other was a sample of Japanese volunteers and used a Calorie Counter accelerometer to estimate kilocalories and steps per day. The current study is the first study to use Yamax Digiwalker pedometers, which are the most reliable and valid pedometers currently available and demonstrated stronger associations with healthy weight than did cardiorespiratory fitness. It is possible that pedometers reflect energy expended during habitual or incidental physical activity better than cardiorespiratory fitness, which results from both physical activity (particularly of a higher intensity) and genetic attributes.

This chapter observed contrasting findings between associations when different adiposity measures were used to define healthy weight in men. When BMI was used to define healthy weight, no significant associations were observed with physical activity or cardiorespiratory fitness. However, when waist circumference was used to define healthy weight, significant associations were observed with both daily steps and cardiorespiratory fitness. This is in contrast to other previous studies, which have observed associations with adiposity and obesity, irrespective of the adiposity measure used. This may be because many previous studies have classified a BMI≤30kg/m^2 as non-obese, while the current study deemed participants with a BMI<25kg/m^2 as healthy weight. It is possible that the effects of physical activity are only seen when comparisons are made with higher levels of BMI. This is plausible because the BMI cutpoint for overweight, particularly in men, may result in the misclassification of more muscular participants as overweight. This may have attenuated the association between physical activity and weight status in this study. To examine this, data were re-examined comparing healthy weight (BMI<25kg/m^2) participants to obese (BMI≥30kg/m^2) participants, rather than to overweight (BMI≥25kg/m^2) participants. Little difference was seen in the associations and these were in some cases weaker (data not shown). However, associations in men in the current study were consistently stronger when waist circumference was used to define healthy weight, which has been observed previously in studies of adiposity (Cameron, Welborn et al. 2003; Koh-Banerjee, Chu et al. 2003; Thompson, Rakow et al. 2004). This suggests that waist circumference may be a better estimate of adiposity in men than BMI, particularly when categorising overweight subjects, or that the relationship between physical activity and central adiposity is stronger than the relationship between physical activity and overall body mass.

Sex differences in the associations between healthy weight and sedentary behaviours were evident in this study. While women who reported higher levels of television viewing, sitting and computer usage had a 14-33% lower prevalence of healthy weight than those reporting less sedentary behaviour, there were no significant associations between sedentary behaviours and healthy weight in men, even at the highest sedentary behaviour levels. This is in contrast to previous cross-sectional studies which have observed strong and consistent positive relationships between adiposity and sedentary behaviours (Tucker and Friedman 1989; Tucker and Bagwell 1991; Kronenberg, Pereira et al. 2000; Salmon, Bauman et al. 2000; Vioque, Torres et al. 2000; McCarthy, Gibney et al. 2002; Cameron, Welborn et al. 2003; Liebman, Pelican et al. 2003). While the reasons for these sex differences are unknown, it is plausible physical activity, physical inactivity and sedentary behaviours interact differently in men and women. It is plausible that in men, television viewing is not associated with physical activity behaviours, while in women higher levels of television viewing may indeed reflect greater levels of physical inactivity. For instance, authors of a South Australian study described three different activity styles for children based on physical activity and sedentary behaviours: "screenies" (low physical activity and high television viewing), "sporties" (high physical activity and low television viewing) and "technoactives" (high physical activity and high screen time). More boys than girls (55% compared with 49%) were "technoactives" (Dollman and Ridley 2006). It is possible that adult males may be more likely to fall into the "technoactive" category, while women may be more likely to either be "screenies" or "sporties". Data from this study support this idea: daily steps were not correlated with television viewing in males (r=0.00), but were inversely correlated in females (r=-0.11, p<0.05). This finding highlights the importance of acknowledging that sedentary behaviour is not simply the inverse of physical activity, and that sedentary behaviour and physical inactivity are quite different concepts.

Few studies have examined the relationship between weight status and sitting or computer usage. Those studies that have examined sitting behaviours in relation to weight status have tended to focus on sitting within specific contexts, such as sitting at work or during leisure time (Brown, Miller et al. 2003; Hu, Li et al. 2003; Mummery, Schofield et al. 2005). In the Nurses' Health Study, women who reported at baseline more time sitting while watching television, at work or away from home or driving had an elevated likelihood of obesity six years later (Hu, Li et al. 2003). The associations were strongest for sitting while watching television. In a study of Australian adults, higher reported time spent sitting was associated with increased likelihood of overweight or obesity, compared with those who reported low levels of sitting (Brown, Miller et al. 2003). Another Australian study found male employees who reported sitting for more than six hours per day at work had higher odds of overweight than those who reported sitting for less than 45 minutes per day (Mummery, Schofield et al. 2005). No association was noted for female employees, in contrast to findings from the current study. These differences in findings may be due to the difference in the measurement of sitting used in the studies – the current study focused on total sitting, while the employee study focused on sitting at work only. It is possible that men who report high levels of sitting at work do not report high levels of sitting outside work, and men that report low levels of sitting at work may report high levels of sitting outside work. This seems plausible because in the current study, men from the highest occupation levels (managers/professionals) reported more leisure time physical activity and less occupational physical activity than men from blue collar or manual occupations (data not shown). For men, only measuring sitting during work time may attenuate the relationship between total sitting and weight status.

This is the first study that has used the IPAQ-L to examine the relationship between physical activity and adiposity in a sample of young Australian adults. Interestingly, no association was evident between healthy weight and self-reported physical activity in either males or females. It seems likely that this is a result of the self-reported measure of physical activity used, the IPAQ-L, given that objectively measured physical activity and cardiorespiratory fitness both demonstrated strong and consistent associations with healthy weight. It is possible that imprecision in the IPAQ-L may have biased results towards the null by underestimating associations. Similar findings were seen in a study of pre-menopausal Brazilian women, where no significant differences in BMI, percent body fat, skinfold thickness, waist to hip ratio, waist circumference or $VO2_{max}$ between women classified as inactive or active based on data from the IPAQ (da Silva, Costa-Paiva et al. 2005). In contrast, a European study examined the relationship between physical activity measured using the IPAQ (short version) and measures of obesity in 757 obese subjects aged 20-50 years (Tehard, Saris et al. 2005). The authors observed weak but significant correlations between total physical activity and abdominal obesity in women, and between total physical activity and general obesity in men (r=-0.16 and -0.19, respectively).

Despite the fact that the IPAQ-L was developed by an international expert consensus group and has demonstrated evidence of reliability and validity, it is plausible that this questionnaire did not adequately "capture" physical activity in this sample of young Australian adults. The IPAQ-L was not reliability or validity tested in this sample, although correlations between total minutes of physical activity were significantly correlated with daily steps in males (r=0.41) and females (r=0.23). These correlations are similar to the median (r=0.33) value reported in a recent review of studies examining the association between pedometer-determined physical activity and self-reported measures (Tudor-Locke, Williams et al. 2002) suggesting that the IPAQ-L may be no better or worse than other self-reported physical activity measures. Over-reporting has been observed previously using the IPAQ short version (Rzewnicki, Vanden Auweele et al. 2003). Given the similar properties of the short and long versions, it is possible that data collected from the IPAQ-L also provides an overestimation of physical activity, attenuating the ability to detect differences in body composition.

While the findings from this chapter highlight some of the difficulties of measuring physical activity, it is possible that the different findings seen between this study and previous research are related to the age of the participants. The current study included young Australian adults aged 26-36 years, while most previous studies have examined this relationship in groups including older populations. It is plausible that the association between physical activity and adiposity may become stronger with age and that associations may be difficult to detect in young, active and relatively healthy adults such as in the current study. Data from the 1989 US Behavioural Risk Factor Surveillance Survey suggests that the strength of the association between body weight and physical activity tends to increase with age (DiPietro, Williamson et al. 1993). It has been hypothesised that because the muscle-to-fat ratio declines with age, physical activity exerts less of an influence on body composition at younger ages, where the effect of exercise may be distorted by increases in muscle mass (DiPietro 1995).

Given the difficulties in measuring self-reported physical activity, pedometers provide a relatively simple and economic objective alternative. However, there remain a number of practical considerations that require clarification so that results of studies can be directly compared. Many of these considerations have been detailed recently and must be considered in future physical activity research using pedometers (Tudor-Locke and Myers 2001; Schmidt, Blizzard et al. In Press). Although recommendations suggest that authors provide more detail on pedometer data cleaning and management protocols, few studies report specific criteria for the inclusion of "valid" pedometer data. For instance, few studies provide information on criteria for minimum daily wear time, whether the pedometer was worn over consecutive or split days, or whether the monitoring period included weekdays and weekends. It is likely that the longer the period of assessment, the more accurately the data represents true habitual activity.

It is possible that the findings from this study are not generalisable to young Australian adults. The sample consisted of adults who agreed to participate in the follow-up of a national survey conducted when they were children. It is possible that participants in this study were in some way different from the general population, for instance, more health conscious, which may have influenced the findings. While the participants in the current study did differ from the general population on some sociodemographic characteristics (as described in section 4.5), particularly level of education, these differences seem unlikely to explain differences in findings between this and other studies. Additionally, the proportion of participants deemed healthy weight, overweight or obese, using either BMI or waist circumference to define weight status, was strikingly similar to that observed in a recent national study of the prevalence of overweight and obesity in Australian adults of a similar age (Cameron, Welborn et al. 2003). Likewise, the proportion of daily smokers was similar in the current study to the national prevalence seen in Australian adults (White, Hill et al. 2003).

In addition to its large sample size and ability to adjust for a number of potential confounders, a key strength of this study was the use of multiple measures of physical activity. The use of an objective measure – pedometers – reduces the likelihood of over- or under-reporting of physical activity and has the added advantage of measuring incidental activity, which is difficult to estimate from questionnaires. The PWC_{170} cycle ergometer test provides an objective measure of cardiorespiratory fitness that is likely to reflect habitual physical activity over time. This is also the largest study to date that has examined the relationship between weight status and physical activity as measured by pedometers. Few studies have had the ability to assess the relationship between weight status, objectively measured physical activity, self-reported physical activity, sedentary behaviour, and cardiorespiratory fitness in a large, population-based sample. Additionally, this relationship had not been examined in young Australian adults demonstrating early risk factors for cardiovascular disease, and who may be prime targets for early intervention and obesity prevention strategies.

In conclusion, higher levels of physical activity and cardiorespiratory fitness were associated with an elevated prevalence of healthy weight in this sample of young Australian adults. This finding was stronger in women than in men, suggesting that the measures used were better at capturing physical activity in women than in men. Interesting differences in associations were also observed across measures of physical activity and fitness. In contrast to previous studies that have predominantly used self-reported measures of physical activity, physical activity measured by pedometers showed stronger associations with weight status than did cardiorespiratory fitness in both men and women. Pedometers may therefore provide a simple and economic alternative to fitness testing in large epidemiological studies of young healthy adults. In men, different associations with physical activity and fitness were observed with different measures of adiposity. When healthy weight was defined using BMI, no associations were seen, but when waist circumference was used associations became evident. This suggests that waist circumference may provide a more accurate estimate of adiposity in men than BMI, and is a quick and reliable procedure that would be a useful inclusion in further research, particularly in men. This chapter also highlighted the difficulties associated with measuring physical activity in large epidemiological investigations. However, the use of multiple measures of physical activity, fitness and sedentary behaviours provided useful insights into the behaviours and of participants and the associations with healthy weight. The measures of physical activity, cardiorespiratory fitness and adiposity used in studies may have important implications for associations observed. Future studies examining the relationship between adiposity and physical activity would also benefit from using multiple measures, which may help to further disentangle behaviours and key relationships with adiposity to further inform the development of obesity prevention strategies.

4.11 Summary

What is already known?

- Physical activity is the only easily modified element of energy expenditure, which is important for energy balance
- There is conflicting evidence about the importance of physical activity and cardiorespiratory fitness in determining weight status in adults
- Few studies have used objective measures of physical activity in a large sample

What was done to learn more?

- 2,053 young Australian adults (aged 26-36 years) were surveyed as part of the Childhood Determinants of Adult Health (CDAH) follow-up study
- Participants completed the IPAQ-L, seven-day pedometer diaries, reported sedentary behaviours and had their fitness, height, weight and waist circumferences measured
- Log binomial regression was used to calculate ratios of prevalence (PR) of healthy weight at different levels of physical activity, fitness and sedentary behaviours

What were the key results?

- Achieving more than 5,000 steps/day for women and 7,500 steps/day for men was associated with a higher prevalence of healthy weight (p for trend <0.01)
- The prevalence of healthy weight was higher in those achieving ≥12,500 steps/day compared to those achieving <5,000 steps/day (PR 1.79, 95% CI: 1.29-2.48 in women; PR 1.60, 95% CI: 1.27-2.02 in men)
- Those in the highest fitness quarter had the highest prevalence of healthy weight (PR 1.39, 95% CI: 1.18-1.64 for women; PR 1.37, 95% CI: 1.18-1.60 for men)
- Those women watching the most television had the lowest prevalence of healthy weight (PR 0.67, 95% CI: 0.55-0.82); no differences were noted for men

What does this study add?

- Healthy weight was more prevalent in physically active and fitter adults than in less active and fit adults, an association that was stronger in women than in men
- The most sedentary women had a significantly lower prevalence of healthy weight than the least sedentary women, but no differences were observed in men
- Objectively measured physical activity showed stronger associations with healthy weight than did cardiorespiratory fitness
- In men, healthy weight defined using waist circumference showed stronger associations with physical activity and fitness than defining healthy weight using BMI
- The measures of physical activity, fitness and adiposity used in studies have important implications for associations that are likely to be detected. Associations tended to differ according to the sex of subjects.

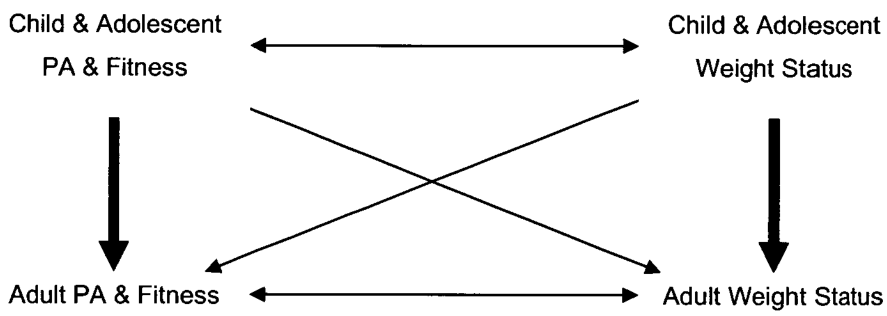
Chapter 5 – Do Adiposity, Physical Activity & Fitness Track from Childhood to Adulthood?

5.1 Introduction

In the previous two chapters, the associations between physical activity, cardiorespiratory fitness and healthy weight status were examined cross-sectionally at two time points, in childhood and in adulthood. For children, higher levels of physical activity were not related to being a healthy weight, but higher levels of cardiorespiratory fitness were. For adults, higher levels of physical activity and cardiorespiratory fitness were associated with being a healthy weight, particularly in women. Self-reported physical activity was not associated with weight status in either men or women, while time spent in sedentary behaviours was associated with weight status in women only.

This chapter focuses on the tracking of adiposity, physical activity and cardiorespiratory fitness, as highlighted in Figure 28.

Figure 28: Conceptual model of the relationships between physical activity, fitness & weight status from childhood & adolescence into adulthood



Adapted from Blair et al (1989)

Tracking refers to the maintenance of relative rank or position within a group over time. Tracking is generally stronger over shorter periods of time with associations weakening with longer periods of follow-up. It is commonly assumed that behaviours developed in childhood remain stable into adulthood. However, the period from childhood and adolescence into adulthood is a time of significant development and change, for example, completion of schooling, leaving the family home, entrance into the workforce, post-secondary education and training, marriage, childrearing and development of disease. Studies that assess longitudinal relationships between childhood behaviours and health outcomes in adulthood are difficult to conduct because they often require a vast amount of time and resources, as well as large numbers of subjects to allow for participant dropout. Therefore, a limited number of prospective cohort studies spanning childhood and adulthood have been conducted.

Tracking is generally analysed in three ways. Many studies calculate correlation coefficients (continuous data) or kappa coefficients (categorical data) to analyse the association between a behaviour or risk factor at two points in time. For behavioural research, correlation coefficients less than 0.30 are interpreted to be low tracking, coefficients greater than 0.30 but less than 0.60 are considered evident of moderate tracking, and coefficients greater than 0.60 are considered high tracking (Malina 1996). Tracking studies usually report the proportion of participants remaining in the same group over time, for instance, the proportion of obese children who became obese adults, or the proportion of participants remaining in the highest third of values for a given variable. Other studies use either logistic or linear regression equations to predict the likelihood of a behaviour or risk factor in adulthood given a particular behaviour or risk factor in childhood (i.e. the likelihood of being an obese adult if obese as a child). Different study designs, age of participants, duration of follow-up and methods of analysis make it difficult to directly compare results from tracking studies.

5.2 Literature Review

The following section provides a critical analysis of previous research that has examined the tracking of adiposity, physical activity and cardiorespiratory fitness from childhood to adulthood. Firstly, studies that have assessed tracking of adiposity or weight status from childhood to adulthood are examined. Secondly, studies that have assessed tracking of physical activity from childhood to adulthood are examined, and thirdly studies that have reported tracking of cardiorespiratory fitness from childhood to adulthood are assessed.

5.2.1 Tracking of Adiposity from Childhood to Adulthood

Tracking of adiposity over short periods of time is generally stronger than tracking over longer periods of time. This was particularly evident in the Amsterdam Growth and Health Longitudinal Study, which observed stronger correlations between body fat at 13 years and body fat at 14 years (r=0.87-0.89), 15 years (r=0.76-0.82), and 16 years (r=0.84-0.77) than at age 21 years (r=0.49-0.55) and 27 years (r=0.22-0.51) (Twisk, Kemper et al. 1995). In the early 1990s, Serdula and colleagues conducted a review of American and European studies published between 1970 and July 1992 that examined the tracking of adiposity from childhood into adulthood (Serdula, Ivery et al. 1993). The authors identified 17 published reports from 15 study populations, with baseline age ranging from 6 months to 16 years, and follow-up age ranging from 18 years to 53 years. Correlation coefficients ranged from –0.04 to 0.84 (median: 0.46 in females, 0.40 in males), were strongest when baseline age was higher and were stronger in studies with shorter duration of follow-up. In addition, stronger correlations were generally observed for weight-for-height indices than for skinfold thickness measures. The authors suggest that this may be because height and weight are subject to less measurement error than skinfold thickness measures. Alternatively, it is possible that adipose tissue is more variable over time than lean body mass. Because adipose tissue is the major component of skinfold thickness measures while weight includes lean body mass, this would result in weight for height measurements showing better tracking than skinfold thickness measures. The largest of these studies by far, the 1946 British Birth Cohort, reported on 3,249 children followed from age 7 through to adults at age 36 years and observed correlations coefficients for weight/height of r=0.28 for males and r=0.40 for females (Braddon, Rodgers et al. 1986). When tracking between the ages of 14 years and 36 years was assessed in the same cohort, stronger correlation coefficients were evident: r=0.46 for males and r=0.60 for females.

Serdula and colleagues also reviewed studies that had examined the relationship between child and adult obesity (Serdula, Ivery et al. 1993). A large proportion of obese children became obese adults (27-63%), with the risk ratio of being an obese adult if obese as a child ranging from 2.0 (95% CI: 1.2-3.3) to 6.5 (95% CI: 4.3-9.8). While being overweight or obese as a child conveyed a significantly higher risk of adult overweight or obesity, only a small proportion of obesity in adulthood was attributable to childhood obesity. The proportion of obese adults who were obese as children ranged from 5-44% (median 21%) and the proportion of adult obesity attributable to childhood obesity was 8-22% (median 12%). The authors attribute the large variation in findings to differences in study design, the ages at which participants were measured, the duration of follow-up and cultural and temporal differences. The findings of this review suggest that while being an obese child significantly increases the risk of becoming an obese adult, a large proportion of adults were in fact healthy weight as children.

Since the Serdula review was conducted, a number of further studies examining tracking of adiposity have been conducted. A summary of the methodological details of studies published after 1992 that have assessed tracking of overweight and obesity from childhood to adulthood is presented in Table 49. Table 50 summarises the main findings from these studies. Where more than one article has reported on the same study population, the article with the longest period between baseline and follow-up has been used.

Table 49: Methodological details of studies that have assessed tracking of adiposity from childhood & adolescence into adulthood

Study (Author/ Year)	N, Sex	Age (years)		Measure of Adiposity	Treatment of Data		Analytic Method (Adjustments)
		Baseline	F/up		Children	Adults	
1958 British Birth Cohort (Power, Lake et al. 1997)	5,512 M & 5,700 F	7, 11 & 16	33	BMI derived from measured (age 7, 11, 16, 33) & self-reported (age 23) height & weight	Treated as a continuous variable		Partial correlation coefficients (measurement date)
Northern Finland Birth Cohort (Laitinen, Power et al. 2001)	2,876 M & 3,404 F	Birth	31	BMI derived from measured (birth, 1 & 31 yrs) & self-reported (14 yrs) height & weight	Owt: BMI> 85th & <95th percentile; Obese: BMI ≥95th percentile	Owt: BMI ≥25kg/m^2 & <30kg/m^2; Obese: BMI≥30kg/m^2	Linear regression (maternal BMI & age, social class, birth weight, BMI at 1 & 14 yrs, age at menarche in females)
Muscatine Coronary Risk Factor Study (Clarke and Lauer 1993)	2,631 M & F	9-18	20-35	BMI derived from measured height & weight	BMI age- & gender-specific percentile ranks defined by quintiles		Pearson correlations (nil)
Bogalusa Heart Study (Freedman, Khan et al. 2005)	1,115 M & 1,495 F	2-17	18-37	BMI derived from measured height & weight	Owt: BMI-for-age≥ 95th centile	Obese: BMI≥30kg/m^2	Spearman correlations (race, childhood age, adult age)
Group Health Cooperative of Puget Sound, USA, Cohort (Whitaker, Wright et al. 1997)	854 M & F	Birth	21-29	BMI derived from measured height & weight	Obese: ≥85th percentile; Very obese: ≥ 95th percentile	Obesity: BMI ≥27.8 (M) & ≥27.3 (F)	Logistic regression (childhood obesity status, number of obese parents, siblings)
Minneapolis Children's Blood Pressure Study (Sinaiko, Donahue et al. 1999)	356 M & 323 F	12.7±0.1	23.6±0.1	BMI derived from measured height & weight	Treated as a continuous variable		Pearson correlations (nil)

Study (Author/ Year)	N, Sex	Age (years)		Measure of Adiposity	Treatment of Data		Analytic Method
		Baseline	F/up		Children	Adults	(Adjustments)
Fels, Guidance, Harvard & Oakland Longitudinal Studies (Guo, Roche et al. 1994)	277 M & 278 F	1	35±5	BMI derived from measured height & weight	Age- & sex-specific centiles based on reference data	Owt: BMI >28.0 (M) & >26 (F)	Pearson correlations (nil); logistic regression
Oslo Youth Study (Kvaavik, Tell et al. 2003)	250 M & 235 F	14.7 ± 1.1	32.4±1.0	BMI derived from measured (baseline) & self-reported (follow-up) height & weight	BMI quartiles		Pearson correlation (nil); logistic regression (Tanner stage, sex)
Northern Ireland Young Hearts Project (Boreham, Robson et al. 2004)	245 M & 231 F	15	22 (±1.6)	BMI derived from measured height & weight; Σ4SF	Categorised into lowest 25%, middle 50%, & highest 25%		Kappa values (nil)
Thousand Families Cohort (Wright, Parker et al. 2001)	529 M & F	9 & 13	50	BMI derived from measured (n=409) & self-reported (n=120) height & weight	Converted to standard deviation scores (based on national reference data) & treated as continuous variables		Correlation (nil)
Dunedin Birth Cohort (Williams 2001)	~400 M & F	3	21	BMI derived from measured height & weight	Owt: BMI>75th percentile	Owt: BMI> 25kg/m^2	M: r=0.32 F: r=0.27
East Boston Blood Pressure Study (Field, Cook et al. 2005)	139 M & 175 F	8-15	~22	BMI derived from measured height & weight	Owt: BMI>85th & <95th centile; obese: BMI>95th percentile	Owt: BMI ≥25kg/m^2 & <30kg/m^2; Obese: BMI≥30kg/m^2	Logistic & linear regression (age, age^2, length of follow-up)
Danish Youth & Sports Study (Andersen and Haraldsdottir 1993)	88 M & 115 F	15-19	23-27	BMI derived from measured height & weight; %BF derived from two skinfold thicknesses	Treated as continuous variables		Pearson correlation (nil)

Study (Author/ Year)	N, Sex	Age (years)		Measure of Adiposity	Treatment of Data		Analytic Method
		Baseline	F/up		Children	Adults	(Adjustments)
Trois-Rivieres Study (Trudeau, Shephard et al. 2001)	M: 96 F: 95	10-12	34	BMI derived from measured height & weight; Σ4SF	Treated as a continuous variable		Pearson correlation (nil)
AGHLS (Twisk, Kemper et al. 1997; Kemper, Post et al. 1999)	181 M & F	13	27	Fat mass estimated from the Σ4SF	Treated as a continuous variable		Generalised estimating equations (nil)
Adelaide Nutrition Study (Magarey, Daniels et al. 2003)	155 M & F	2	20	BMI derived from measured height & weight	BMI converted to SD scores	Owt: BMI ≥25kg/m^2 & <30kg/m^2; Obese: BMI≥30kg/m^2	Pearson correlation (nil), regression

AGHLS: Amsterdam Growth & Health Longitudinal Study
M: male; F: female; NS: non-significant; OR: odds ratio; RR: relative risk; NR: not reported; SD: standard deviation; IOTF: International Obesity Task Force
BMI: body mass index; WHR: waist to hip ratio; % BF: per cent body fat; ΣSF: sum of skinfolds; owt: overweight

Table 50: Results of studies that have assessed tracking of adiposity from childhood & adolescence into adulthood

Study (Author/ Year)	Childhood Weight Status	Adult Weight Status		Correlations/ Kappas	Regression
		Overweight (%)	Obese (%)		
1958 British Birth Cohort (Power, Lake et al. 1997)	>91st percentile	M: 35.7-43.8 F: 27.7-38.6	M: 34.3-60.0 F: 37.9-66.0	M: r=0.33-0.75 F: r=0.37-0.74	N/A
	>95 percentile	M: 26.6-41.2 F: 17.2-33.3	M: 38.4-68.2 F: 44.0-79.0		
	>98th percentile	M: 16.0-36.6 F: 5.8-33.7	M: 43.0-78.0 F: 57.4-91.3		
Northern Finland Birth Cohort (Laitinen, Power et al. 2001)	<85th percentile (normal)	M: 38 F: 18	M: 4 F: 4	N/A	M: β=0.71 (0.67-0.76) F: β=1.02 (0.96-1.07)
	85<95th percentile (owt)	M:56 F: 42	M: 25 F: 22		
	≥95th percentile (obese)	M: 41 F: 27	M: 47 F: 55		
Muscatine Coronary Risk Factor Study (Clarke and Lauer 1993)	81-100th percentile	M: 47.9-75.0[1] F: 50.0--87.5%		M: r=0.58-0.91 F: r=0.59-0.75	N/A
Bogalusa Heart Study (Freedman, Khan et al. 2005)	85-94th percentile		M: 45-93 F: 52-69	M: r=0.50-0.74 F: r=0.45-0.68	N/A
	≥95th percentile		M: 76-93 F: 52-69		
Group Health Cooperative of Puget Sound, USA, Cohort (Whitaker, Wright et al. 1997)	85-94th percentile	N/A	19-75	N/A	OR: 1.3-28.3
	≥95th percentile		26-83		OR: 2.0-28.3
Minneapolis Children's Blood Pressure Study (Sinaiko, Donahue et al. 1999)	Treated as a continuous variable	N/A	N/A	r=0.61	N/A
Fels, Guidance, Harvard & Oakland Longitudinal Studies (Guo, Roche et al. 1994)	≥95th percentile	M: 21-78[2] F: 19-74		Range from r=0.08-0.20 at age 1 to 0.62-0.76 at age 18	M: 2.0-57.5[3] F: 2.1-35.6

[1] Adult BMI in the 81st-100th percentile

Study (Author/ Year)	Childhood Weight Status	Adult Weight Status		Correlations/ Kappas	Regression
		Overweight (%)	Obese (%)		
Oslo Youth Study (Kvaavik, Tell et al. 2003)	Quartile 1	19.8	0.8	r=0.54	OR: 0.02 (0.002-0.14)[4]
	Quartile 2	30.6	3.3		OR: 0.08 (0.03-0.23)
	Quartile 3	44.2	5.0		OR: 0.13 (0.05-0.33)
	Quartile 4	65.0	27.5		OR: 1.0 (ref)
Northern Ireland Young Hearts Project (Boreham, Robson et al. 2004)	Treated as continuous variables	N/A	N/A	BMI M: κ=0.42 F: κ=0.45 Σ4SF M: κ=0.22 F: κ=0.36	N/A
Thousand Families Cohort (Wright, Parker et al. 2001)	9 years <25th percentile 25-74th percentile 75-90th percentile >90th percentile 13 years <25th percentile 25-74th percentile 75-90th percentile >90th percentile	N/A	9 years 8 12 28 42 13 years 5 14 22 45	9 years: r=0.24 13 years: r=0.39	N/A
Dunedin Birth Cohort (Williams 2001)	<50th percentile	N/A	N/A	M: r=0.32-0.86 F: r=0.27-0.84	M: 1.0 (ref) F: 1.0 (ref)
	50-75th percentile				M: 2.3-5.3 F: 1.5 (NS)-3.6
	>75th percentile				M: 4.0-9.8 F: 3.2-6.8

[2] Adult BMI ≥28 in males & 26 in females
[3] Values are odds ratios for comparison between BMI≥ 95th with BMI<50th percentile
[4] Adult BMI≥30kg/m^2

Study (Author/ Year)	Childhood Weight Status	Adult Weight Status		Correlations/ Kappas	Regression
		Overweight (%)	Obese (%)		
East Boston Blood Pressure Study (Field, Cook et al. 2005)	<50th percentile 50-74th percentile 75-84th percentile ≥85th percentile	N/A	N/A	N/A	M: 1.0, F: 1.0[5] M: 5.3, F: 4.8 M: 4.3, F: 20.2 M: 13.2, F: 48.2
	<50th percentile 50-74th percentile 75-84th percentile ≥85th percentile				M: 1.0, F: 1.0[6] M: 2.2, F: 2.0 M: 2.6, F: 3.3 M: 5.6, F: 6.2
Danish Youth & Sports Study (Andersen and Haraldsdottir 1993)	Upper quintile	BMI M: 59[7] F: 71 %BF M: 43 F: 33		BMI M: r=0.80 F: r=0.77 %BF M: r=0.72 F: r=0.46	N/A
Trois-Rivieres Study (Trudeau, Shephard et al. 2001)	Treated as a continuous variable	N/A	N/A	BMI M: r=0.43-0.49 F: r=0.64-0.70 Σ4SF M: r=0.23-0.56 F: r=0.45-0.61	N/A
AGHLS (Twisk, Kemper et al. 1997; Kemper, Post et al. 1999)	Treated as a continuous variable	N/A	N/A	Stability coefficient of 0.63 (95% CI: 0.56-0.71)	Odds of high risk Σ4SF in adulthood if high risk in childhood; OR: 17.7
Adelaide Nutrition Study (Magarey, Daniels et al. 2003)	BMI ≥ IOTF age- & sex-specific cutpoints for owt	2 years: 83.3[8] 8 years: 76.0 11 years: 76.0 15 years: 86.2		M: r=0.44-0.74 F: r=0.30-0.61	2 years: RR: 2.72 (1.81-4.10) 8 years: RR: 3.47 (2.41-5.01) 11 years: RR: 3.55 (2.43-5.21) 15 years: RR: 4.28 (3.01-6.08)

N/A: not applicable; AGHLS: Amsterdam Growth & Health Longitudinal Study; M: male; F: female; NS: non-significant; OR: odds ratio; RR: relative risk; NR: not reported; SD: standard deviation

[5] Values are odds ratios for comparison between BMI≥ 85th with BMI<50th percentile
[6] Values are β coefficients from linear regression analyses for comparison between BMI≥ 85th with BMI<50th percentile
[7] Proportion of participants in the upper quintile in childhood & adulthood
[8] Proportion of participants deemed overweight in childhood & overweight (BMI≥25kg/m^2) in adulthood

The sample sizes in the studies examined here ranged from 155 (Magarey, Daniels et al. 2003) to 11,212 (Power, Lake et al. 1997). Irrespective of the number of participants, most studies saw evidence of at least moderate tracking. The longest period of follow-up was 35 years (Guo, Roche et al. 1994) and the shortest was seven years (Boreham, Robson et al. 2004). In general, stronger associations were seen when the period of follow-up was shorter and when participants were older at baseline, consistent with earlier studies. Nearly all studies used BMI calculated from measured height and weight to estimate adiposity, while some additionally used skinfold measures (Andersen and Haraldsdottir 1993; Twisk, Kemper et al. 1997; Kemper, Post et al. 1999; Trudeau, Shephard et al. 2001; Boreham, Robson et al. 2004).

Results from the 16 studies presented in the tables provide consistent evidence for the strong tracking of BMI from childhood to adulthood. The strength of the association generally increased with increasing age in childhood. Correlation coefficients ranged from r=0.02 for boys aged 1 year at baseline and 35 years at follow-up (Guo, Roche et al. 1994) to r=0.91 for boys age 13-14 years at baseline and 31-35 years at follow-up (Clarke and Lauer 1993). The median correlation coefficient from the values reported here was r=0.63. Different studies used different cutpoints to define overweight and obesity in childhood and in adulthood, making it difficult to compare the proportion of participants falling into each category across studies. However, in general, a large proportion of those children whose BMI or skinfold thicknesses were at the upper end of the distribution or who were deemed overweight or obese were also overweight or obese as adults. Additionally, the likelihood of being overweight or obese as an adult was significantly greater for those children in the upper end of the distribution or those already overweight or obese. The strength of this association increased with increasing childhood age. While none of these papers focused on healthy weight status as an outcome, the Bogalusa Heart Study showed that 64% of white males and 80% of white females whose BMI in childhood was less than the 50th percentile had a BMI in adulthood less than 25kg/m^2 (Freedman, Khan et al. 2005). 36% of white males and 55% of white females whose BMI in childhood was between the 50th and 85th percentiles had a BMI in adulthood less than 25kg/m^2. The findings indicate that the lower the childhood BMI, the greater the likelihood of being a healthy weight as an adult, particularly for females.

Results from these more recent studies support Serdula's (1993) conclusion that adiposity tracks well from childhood to adulthood. The median correlation coefficient seen in the later studies reviewed here (1992 onwards) is higher than that reported by Serdula from studies between 1970 and 1992 (0.63 vs 0.40-0.46). Similarly, Serdula and colleagues concluded that a significant proportion of obese children (26-63%) become obese adults, and that the risk of becoming an obese adult was significantly greater (risk ratio range: 2.0-6.5) if obesity was present in childhood. Some authors have argued that with the increasing prevalence of overweight and obesity, higher levels of tracking from childhood to adulthood are more likely to be observed (Magarey, Daniels et al. 2003), which may explain the higher median correlation coefficients observed in the later studies. The strong and consistent association between childhood and adulthood adiposity spanning different lengths of follow-up, different decades, different countries and different ages at baseline and follow-up highlights the strength of childhood and adolescent adiposity as a predictor of adult adiposity. Very few overweight or obese children become healthy weight adults, highlighting the importance of obesity prevention from an early age, although most overweight or obese adults were healthy weight as children. This finding demonstrates the necessity for ongoing obesity prevention strategies that continue throughout childhood and adolescence into adulthood.

Only one study assessed tracking of overweight and obesity in an Australian population, in a small South Australian study (Magarey, Daniels et al. 2003), which observed results consistent with other studies. In addition, this was the only study to use the recently developed IOTF cutpoints to define childhood overweight and obesity, which provide internationally comparable results. All other studies used country-specific national reference standards, which make it difficult to compare results directly.

5.2.2 Tracking of Physical Activity from Childhood to Adulthood

Varying physical activity measures and methods of analysis make it difficult to compare results and make firm conclusions about physical activity tracking from childhood and adolescence into adulthood. However, physical activity tracking studies that span the period from childhood to adulthood provide conflicting results. Some have attributed these inconsistencies to methodological flaws (Malina 1996), such as the inability of some measures to fully "capture" physical activity behaviours. However, physical activity, similar to adiposity, appears to show stronger tracking over shorter periods of time than longer periods of time (Malina 1996). This was particularly evident in the Amsterdam Growth and Health Longitudinal Study, where physical activity at age 13 years showed strongest correlations with physical activity at age 14 years (r=0.47-0.64), 15 years (r=0.38-0.55), 16 years (r=0.44-0.58) than at age 21 years (r=0.18-0.20) and 27 years (r=0.05-0.17) (Twisk, Kemper et al. 2001).

In a review of physical activity and physical fitness tracking studies, the correlation between adolescent and adult physical activity ranged from r=0.05-0.54 in males and r=0.11-0.37 in females; for aerobic fitness the correlations ranged from r=0.30-0.41 in males and r=0.36-0.46 in females (Malina 2001). The author of the review concluded that physical activity generally tracked at low to moderate levels and physical fitness generally tracked at moderate levels. However, the difficulties in assessing physical activity were highlighted and it was suggested that measurement error may bias findings towards the null hypothesis. For comparison, biological variables such as blood pressure and blood lipids tend to show better tracking (moderate to high). For instance, the Bogalusa Heart Study reported correlations between child and adult total cholesterol ranging from r=0.4-0.6, r=0.1-0.4 for triglycerides, r=0.2-0.4 for HDL-cholesterol, r=0.3-0.6 for low-density lipoprotein (LDL) cholesterol (Bao, Srinivasan et al. 1996) and r=0.41-0.52 for systolic blood pressure and r=0.21-0.40 for diastolic blood pressure (Bao, Threefoot et al. 1995). The Amsterdam Growth and Health Longitudinal Study observed similar moderate to high correlations between child and adult biological measures: r=0.60-0.83 for total cholesterol, r=0.47-0.71 for HDL cholesterol, r=0.41-0.53 for systolic blood pressure and r=0.44-

0.65 for diastolic blood pressure (Twisk, Kemper et al. 1995). Low tracking has been observed for dietary patterns, with the Northern Ireland Young Hearts cohort observing kappa coefficients less than 0.20 (Boreham, Robson et al. 2004).

A summary of prospective longitudinal studies that have assessed the tracking of physical activity is provided in Table 51. This table provides information on the study and author, the number of participants (by sex if possible), age at baseline and follow-up, the physical activity measures used at baseline and follow-up, the analytic approach and statistical adjustments, and significant findings. Where more than one article reports on the results from one study, the paper with the longest period between baseline and follow-up has been used.

Table 51: Tracking of physical activity from childhood & adolescence into adulthood: a summary of prospective longitudinal studies

Study/Author	N	Age (years)		Physical Activity Measure		Analyses	Significant Findings
		Baseline	Follow-up	Baseline	Follow-up	(Adjustments)	
Nth Finland Birth Cohort (Tammelin, Nayha et al. 2003)	2,488 M & 2,798 F	14	31	Self-reported frequency & type of extracurricular sports participation	Self-reported usual duration & frequency of light & moderate PA; past year sports participation	Multinomial logistic regression (nil)	Participation in sports at least 2/week for boys & 1/week for girls at baseline associated with being active or very active at follow-up (OR: 1.6-4.0 & 1.5-2.9 for M & F respectively)
UK Birth Cohort (Kuh and Cooper 1992)	3,332	13-15	36	Teacher rating of sports ability (13 yrs) & energy level (15 yrs)	Self-reported occupational, LTPA, cycling & walking, household/yard PA (adapted Minnesota LTPA questionnaire)	Multivariate logistic regression (education, sex, extraversion, mother's education, childhood ill health)	Above average ability in sports & high energy level in adolescence associated with ↑ PA in adulthood (OR: 1.35 & 1.62, respectively)
Young Finns (Telama, Yang et al. 1997)	1,398 M & F	9-18	21-30	Self-reported frequency & intensity of LTPA, & frequency of sports club competitions & training	Self-reported frequency & duration of intense PA; sports club membership	Spearman's rank order correlations & stepwise multiple regression (nil)	9 year correlations ranged from 0.25-0.47 in boys & 0.18-0.41 in girls; 12 year correlations ranged from 0.15-0.27 in boys & -0.01(NS) - 0.27 in girls; organised competitive sport, physical education grade & intensity of PA in adolescence best predictors of adult PA

Study/Author	N	Age (years)		Physical Activity Measure		Analyses	Significant Findings
		Baseline	Follow-up	Baseline	Follow-up	(Adjustments)	
Young Finns (Telama, Yang et al. 2006)	735 M & 871 F	9-18	30-39	Self-reported participation in organised sports club training & competitions	Self-reported frequency & duration of intense PA; sports club membership	Multinomial logistic regression	M: Participation in sports club training at least once per week ↑ odds of adult PA (OR: 3.25-5.11), as did sports club participation at any level (OR: 3.16-13.46) F: Participation in sports club training many times/week ↑ odds of adult PA (OR: 6.00), as did sports club participation at the national level (OR: 3.29), but not at the sport club or regional level
Nth Ireland Young Hearts (Boreham, Robson et al. 2004)	245 M & 231 F	15	22.0±1.6	Self-reported habitual PA incl. transport to/from school, PA during school beaks, after school sports participation	Self-reported work, sports & LTPA (modified Baecke questionnaire)	Weighted kappa statistics (nil)	PA tracked at low but significant levels in males (κ=0.20); no tracking in females (κ=0.02)
Swedish stratified sample (Barnekow-Bergkvist, Hedberg et al. 1996)	194 M & 179 F	16.1±0.33	33.7±0.74	Self-reported leisure time sports activity, no. of sports & activities & sports club membership	Self-reported type, intensity, frequency & duration of sports & rec. activities, cycling/ walking to work	Spearman's rank order correlations & logistic regression (nil)	No correlation between PA at baseline & follow-up in males (r=0.1) or females (r=0.0); participation in leisure sports (M) & sports club membership (F) at baseline ↓ the risk of physical inactivity as an adult
Danish Youth & Sports Study (Andersen and Haraldsdottir 1993)	88 M & 115 F	15-19	24-28	Self-reported weekly duration of sports activities in the past year	Self-reported weekly duration of sports activities in the past year	Pearson correlation coefficients	PA tracked moderately in men (r=0.31, p<0.001) & women (r=0.20, NS); 53% of M & 8% of F stayed in the upper quintile of PA

Study/Author	N	Age (years)		Physical Activity Measure		Analyses (Adjustments)	Significant Findings
		Baseline	Follow-up	Baseline	Follow-up		
Amsterdam Growth & Health Longitudinal Study (Twisk, Kemper et al. 2000)	83 M & 98 F	13.1±0.8	27.1±0.8	Interview-administered self-reported intensity, duration & frequency of habitual PA (school, work, sports & leisure) in past 3 months	Interview-administered self-reported intensity, duration & frequency of habitual PA (school, work, sports & leisure) in past 3 months	Generalised estimating equations used to calculate stability coefficient & odds ratio (time, gender, biological age, diet, alcohol, smoking)	Daily PA tracked significantly at low-moderate levels; stability coefficient of 0.34 (95% CI: 0.19-0.49); OR: 3.6 (95% CI: 2.4-5.4)
Trois-Rivieres Growth & Development study (Trudeau, Laurencelle et al. 2004)	79 M & 87 F	6-12	35	Self-completed 2-day PA diary	Self-reported exercise or physical work at least 3 times/week (yes/no)	Pearson correlation & t-test	Adolescent PA not correlated with adult PA, except organised sport in adolescence with adult PA in M (r=0.26); more active adult F spent more time in some childhood activities than less active F
Quebec Family Study subsample (Campbell, Katzmarzyk et al. 2001)	77 M & 76 F	8-18	20-30	Self-completed 3-day PA record (15 min intervals)	Self-completed 3-day PA record (15 min intervals)	Spearman's partial rank order correlations (baseline age, length of follow-up) & multiple regression (age, length of follow-up)	Child & adult daily energy expenditure & MVPA not correlated in M or F; physical inactivity between baseline & follow-up correlated in M (r=0.25), but not F; inactivity in youth a significant predictor of adult PA in M only (β=0.06)
Swedish random sample (Glenmark, Hedberg et al. 1994)	62 M & 43 F	16	27	Self-reported frequency & duration of LTPA; sports club membership; rating of work PA	Self-reported frequency & duration of LTPA; sports club membership; rating of work PA	Linear regression	Number of physical & competitive activities & total amount of training at baseline predicted PA index at follow-up in males & females in multivariate analyses

LTPA: leisure time physical activity; MVPA: moderate to vigorous physical activity; NS: non-significant; OR: odds ratio

Overall, there is evidence that physical activity tracks at low levels from childhood into adulthood. Most tracking studies use sports participation or leisure time physical activity as an indicator of physical activity. Few have assessed whether different types of childhood activities show stronger tracking with different types of adult activity. For instance, it would be of public health interest to determine whether different types of childhood activities are related to participation in different types of adult activities so these activities may be further encouraged and supported. Tracking of physical activity from childhood to adulthood has not been reported in an Australian sample, where behaviours may differ due to cultural, structural and social differences. The methodological limitations and varying methods of analysis combined with Malina's hypothesis of bias towards the null suggests that if a more comprehensive or objective measure of physical activity had been used, tracking may be more apparent than the evidence currently suggests. However, it is also plausible that physical activity is such a variable behaviour and that the transition from childhood and adolescence into adulthood brings about such significant lifestyle changes that childhood physical activity has little influence on adult physical activity.

While most studies found some evidence of physical activity tracking, associations were generally weak and tended to be stronger in males than females. Of the 11 studies examined, two presented results combined for males and females, both of which saw a positive association between physical activity in childhood and physical activity in adulthood (Kuh and Cooper 1992; Glenmark, Hedberg et al. 1994; Twisk, Kemper et al. 2000). Most studies that reported results for males saw a positive relationship between childhood physical activity and adult physical activity (Andersen and Haraldsdottir 1993; Glenmark, Hedberg et al. 1994; Telama, Yang et al. 1997; Campbell, Katzmarzyk et al. 2001; Tammelin, Nayha et al. 2003; Boreham, Robson et al. 2004; Telama, Yang et al. 2006), although some saw no association (Barnekow-Bergkvist, Hedberg et al. 1996; Trudeau, Laurencelle et al. 2004). Only two studies observed positive tracking of physical activity from childhood to adulthood in females (Glenmark, Hedberg et al. 1994; Twisk, Kemper et al. 2000), while most saw no evidence of tracking (Andersen and Haraldsdottir 1993; Barnekow-Bergkvist, Hedberg et al. 1996; Telama, Yang et al. 1997; Campbell, Katzmarzyk et al. 2001; Boreham, Robson et al. 2004; Trudeau, Laurencelle et al. 2004) (Telama, Yang et al. 1997). None of the studies presented results stratified by age or an indicator of age (such as school level), which may provide important information for physical activity promotion strategies about the critical periods when positive or negative physical activity tracking may be more likely to occur. In addition, few studies had the ability to assess tracking of physical activity across different domains of physical activity and none examined whether physical activity tracking differed when assessing different types of physical activity.

Five of the 11 studies reviewed had sample sizes <250, with the rest ranging in size from 373 to 5,286. Of the larger studies, most found low to moderate levels of tracking, but key limitations were evident. For instance, in a UK population-based sample (Kuh and Cooper 1992), teachers' reports of students' sports ability and energy levels were used as indicators of physical activity. It is possible that these measures were not measuring physical activity participation, but were measuring some other marker that may influence physical activity participation which may in fact underpin the likelihood of tracking (e.g. personality type or enjoyment of physical activity). Both the Northern Finland Birth Cohort study (Tammelin, Nayha et al. 2003) and the Young Finns study (Telama, Leskinen et al. 1996) focused on leisure and sport activity only, disregarding other important domains of physical activity such as active commuting, school sport, school physical education, recess and lunchtime activity and active play. While the Northern Ireland Young Hearts Study used a comprehensive questionnaire that included more domains of physical activity (habitual physical activity including transport to/from school, physical activity during school beaks and after school sports participation), their study was limited to 15 year olds only at baseline, when physical activity patterns may already be becoming established (Boreham, Robson et al. 2004).

A further complication is the diversity of the methods of analysis used to examine tracking of physical activity. Some studies have reported Pearson or Spearman correlation coefficients to determine whether a correlation exists between physical activity in childhood and adulthood. Other studies have relied on Kappa statistics and percent agreement to assess tracking. Some studies have used logistic regression to determine whether physical activity in childhood can predict the likelihood of participating in physical activity in adulthood. The Amsterdam Growth and Health Longitudinal Study used generalised estimating equations and the Young Finns used simplex models to assess tracking of physical activity. Each of these methods have their advantages and disadvantages, which have been discussed elsewhere (Twisk, Kemper et al. 1994; Wang and Wang 2003). For instance, kappa coefficients can be low despite high levels of agreement as indicated by correlations and probability of tracking, and extreme values (very low or very high) tend to show better tracking.

5.2.3 Tracking of Cardiorespiratory Fitness from Childhood to Adulthood

Fewer studies have examined the tracking of cardiorespiratory fitness from childhood to adulthood. A summary of these studies is presented in Table 52. Of the six studies reviewed, three saw moderate tracking of cardiorespiratory fitness in males and females (Andersen and Haraldsdottir 1993; Twisk, Kemper et al. 2000; Campbell, Katzmarzyk et al. 2001). The Northern Ireland Young Hearts Study observed low levels of tracking in males but not females (Boreham, Robson et al. 2004), while a Swedish study observed low levels of tracking in females but not males (Barnekow-Bergkvist, Hedberg et al. 1996). In contrast, the Trois-Rivieres Growth and Development Study saw low to moderate levels of tracking in females, but inconsistent findings for males (Trudeau, Shephard et al. 2003).

Table 52: Tracking of cardiorespiratory fitness from childhood & adolescence into adulthood: a summary of prospective longitudinal studies

Study/Author	N	Age (years)		Cardiorespiratory Fitness Measure		Analysis (Adjustments)	Findings
		Baseline	Follow-up	Baseline	Follow-up		
Nth Ireland Young Hearts (Boreham, Robson et al. 2004)	245 M & 231 F	15	22.0±1.6	20 metre shuttle test used to estimate VO_2max	VO_{2max} estimated from a PWC_{170} cycle ergometer test	Weighted kappa statistics (nil)	M: κ=0.15 F: κ=0.08 (NS)
Swedish stratified sample (Barnekow-Bergkvist, Hedberg et al. 1996)	194 M & 179 F	16.1±0.33	33.7±0.74	Distance walked/ran in 9 minutes	VO_{2max} estimated from a submaximal cycle ergometer test with one workload	Linear regression	M: No relationship F: 9-min run time associated with VO_2max (β=0.29)
Danish Youth & Sports Study (Andersen and Haraldsdottir 1993)	88 M & 115 F	15-19	24-28	VO_{2max} estimated from a progressive cycle ergometer test (adjusted for body weight)	VO_{2max} estimated from a progressive cycle ergometer test (adjusted for body weight)	Pearson correlation coefficients	M: r=0.35 F: r=0.48
Amsterdam Growth & Health Longitudinal Study (Twisk, Kemper et al. 2000)	83 M & 98 F	13.1±0.8	27.1±0.8	VO_{2max} estimated from a maximal running test on a treadmill (adjusted for body weight)	VO_{2max} estimated from a maximal running test on a treadmill (adjusted for body weight)	Generalised estimating equations used to calculate stability coefficients & odds ratios (time, gender, biological age, diet, alcohol, smoking)	Stability coefficient: 0.31 (95% CI: 0.24-0.38); OR: 4.4 (95% CI: 2.6-7.4)

Study/Author	N	Age (years)		Cardiorespiratory Fitness Measure		Analysis (Adjustments)	Findings
		Baseline	Follow-up	Baseline	Follow-up		
Trois-Rivieres Growth & Development study (Trudeau, Shephard et al. 2003)	79 M & 87 F	6-12	35	PWC_{170} estimated from a cycle ergometer test	PWC_{170} estimated from a cycle ergometer test	Pearson correlation & t-test	M: r=0.23(NS)-0.34 F: r=0.24-0.39 50% & 30% of M & F (respectively) in the upper fitness tertile as children remained there as adults; 40% & 50% of M & F in the lower tertile as children remained there as adults
Quebec Family Study subsample (media recruitment) (Campbell, Katzmarzyk et al. 2001)	77 M & 76 F	8-18	20-30	PWC_{150} estimated from a cycle ergometer test (adjusted for body weight)	PWC_{150} estimated from a cycle ergometer test (adjusted for body weight)	Spearman's rank order correlations & multiple regression (baseline age, length of follow-up) & multiple regression (age, length of follow-up)	M: r=0.24; baseline fitness predicted adult fitness (β=0.05) F: r=0.46; baseline fitness predicted adult fitness (β=0.21)

VO_{2max}: maximal oxygen uptake; NS: non-significant

Similar to tracking of physical activity and adiposity, different methods of analysis make it difficult to compare results directly. The studies reviewed here used Pearson and Spearman correlations, kappa statistics, linear regression, and generalised estimating equations. Again, these differing methods make it difficult to directly compare results, but do enable broad statements about the findings (i.e. low, moderate or high tracking). All studies had a sample size less than 500 and four of the six studies examined cardiorespiratory fitness tracking in a sample size less than 250. It is possible that differences in measures of cardiorespiratory fitness, differences in the length of follow-up and differences in age at baseline may be responsible for some of the differences in the findings. While four of the six studies examined used the same measure of cardiorespiratory fitness at baseline and at follow-up (Andersen and Haraldsdottir 1993; Twisk, Kemper et al. 2000; Campbell, Katzmarzyk et al. 2001; Trudeau, Shephard et al. 2003), two used a field-based measure in childhood and a laboratory-based measure in adulthood (Barnekow-Bergkvist, Hedberg et al. 1996; Boreham, Robson et al. 2004). These two studies also observed weaker findings and inconsistencies between males and females, which may be a result of the different measures used. Age at baseline ranged from 6 years to 16 years and average length of follow-up ranged from 7 years to 24 years. While stronger tracking was seen for physical activity and adiposity across shorter time spans, reported findings for cardiorespiratory fitness tracking were not necessarily similar for similar lengths of follow-up or for similar baseline ages. It is therefore unlikely that length of follow-up or age at baseline is responsible for differences in findings.

Overall, the findings from these studies suggest that cardiorespiratory fitness consistently shows better tracking than physical activity, which is likely related to two main factors. First, physical activity is a modifiable behaviour that is influenced by personal, social and environmental factors, while cardiorespiratory fitness is a physical attribute influenced by genetic and morphological factors, as well as by physical activity. It is likely that the factors that influence physical activity change over time, for instance, peers may be more influential on physical activity in childhood, while competing demands such as work and child-rearing may be more influential in adulthood. The genetic and morphological factors that influence cardiorespiratory fitness may be more stable and therefore better tracking is seen for fitness. Second, self-reported measures of physical activity are likely to be subject to more error than objective measures of cardiorespiratory fitness. Self-reported physical activity measures – which have been used in all tracking studies to date – may lack the sensitivity to provide an accurate estimate of usual physical activity behaviours, while cardiorespiratory fitness may be more likely to reflect habitual physical activity levels. It is likely that a combination of these two factors result in the lower levels of tracking seen for physical activity than cardiorespiratory fitness.

5.3 Aims & Research Questions

While a number of studies have examined the tracking of adiposity, physical activity or cardiorespiratory fitness from childhood to adulthood, none have been conducted in a young Australian population and none have examined these relationships in the same population. Only one other report has used the IOTF cutpoints to define weight status in childhood. All studies that have examined cardiorespiratory fitness tracking have been relatively small in size (n<500) which may not allow for stratification and analysis of specific subgroups (such as age and sex). Larger studies have used different measures of fitness at baseline and follow-up. The aim of this chapter was to examine tracking of measures of adiposity, physical activity and cardiorespiratory fitness from childhood to adulthood in a large sample of young Australians. The specific research questions were:

1. Do healthy weight children become healthy weight adults?
2. Do measures of adiposity track from childhood to adulthood?
3. Does physical activity track from childhood to adulthood?
4. Does cardiorespiratory fitness track from childhood to adulthood?

5.4 Methods

The following section describes the methodology employed in this chapter. First, the sample and participants are discussed. Second, the measures used in the study are summarised (more detail is provided in Chapter 2). Finally, the statistical methods used in this chapter are described.

5.4.1 Participants

The subjects were participants in the ASHFS 1985 who also took part in the CDAH follow-up study. The sample is described in detail in Chapter 2. Briefly, 8,498 children aged 7-15 years were randomly selected from 109 government, Catholic and independent schools from all states and territories in Australia. Schools were selected with a probability proportional to size and children were then selected using simple random sampling. In 2004-6, 2,053 young adults aged 26-36 years participated in the CDAH follow-up study (32% of those successfully traced and residing in states where data collection had taken place up until December 2005). Participants were eligible for inclusion in the current study if they were aged 9-15 years at baseline and had at least one of the following:

- BMI at both time points or waist circumference at both time points
- Self-reported physical activity data at both time points
- Cardiorespiratory fitness data at both time points

Table 53 presents the number of participants who had data available for each of the various components of analysis for this chapter.

Table 53: Number of participants & type of data available for adiposity, physical activity & cardiorespiratory fitness at baseline & follow-up in the CDAH follow-up study

Type of Measure	Baseline Measure	Follow-Up Measure	Males	Females	Total
Measures of Adiposity	BMI	BMI	982	997	1,979
	Waist Circumference	Waist Circumference	982	997	1,979
Physical Activity	Self-Report	Self-Report	1,036	1,180	2,216
Cardiorespiratory Fitness	PWC_{170}	PWC_{170}	275	266	541

5.4.2 Measures

The measures used in this chapter are described in detail in Chapter 2. Briefly, all children had their height, weight and waist girths measured. Children aged 9-15 years completed a questionnaire that asked about the frequency, duration and intensity of physical activity (school sport, school physical education, active commuting and other activities) in the past week; the number of extracurricular sports participated in during the past year; and the intensity of usual physical activity at recess and lunchtime at school. As an estimate of cardiorespiratory fitness, children aged 9, 12 and 15 years completed a PWC_{170} cycle ergometer test, as described in Chapter 2.

At follow-up, a trained technician measured height to the nearest 0.1cm using a Leicester stadiometer; weight to the nearest 0.1kg using Schoenle digital scales; and waist girths to the nearest 0.1cm. The long version of the International Physical Activity Questionnaire (IPAQ-L) was completed, a questionnaire which has shown acceptable levels of validity and reliability in 12 countries (Craig, Marshall et al. 2003). While information on daily steps was collected using pedometers, this data were not included in these analyses because of a lack of comparable baseline data. Participants completed a PWC_{170} cycle ergometer test, which involved administering increasing workloads over three four-minute periods to raise heart rate within predetermined ranges. Sociodemographic information (employment status, occupation, education level, marital status, smoking, and parity in females) was collected via a general self-completed questionnaire.

5.4.3 Statistical Methods

Definitions

As described in the previous two chapters, weight (kilograms) was divided by height squared (metres) to calculate BMI (kg/m^2). BMI was treated both as a continuous and categorical variable. For children, a BMI less than the IOTF age-and sex-specific cutpoints for overweight was defined as a healthy weight. For adults, a BMI <25kg/m^2 was deemed a healthy weight. Waist girth in children and adults was treated continuously. While there are cutpoints for healthy weight and overweight using waist circumference in adults, there are none that are well-accepted for children; therefore this measure was not assessed categorically.

Weekly childhood physical activity was calculated from the sum of self-reported duration and frequency in school sport, school physical education, active commuting to and from school, and other activities. In addition, children reported their participation in extracurricular sports (number of sports played in the past year), and the intensity of physical activity at recess and lunchtime was estimated from a question on usual activities during school breaks (low, low-moderate, moderate-high, high). For adults, weekly time (minutes) and energy (METs) spent in domains of physical activity (leisure, commuting, occupational, household/yard) and time (minutes) spent in intensity of physical activity (walking, moderate, vigorous) were estimated from the IPAQ-L. These physical activity variables were treated both as continuous and categorical variables. As described in the previous chapter, the IPAQ protocol (www.ipaq.ki.se) was used to develop three categories of activity: low, moderate and high (Table 54).

Table 54: Classification of self-reported physical activity using the IPAQ-L scoring protocol

1. Low Active	2. Moderate Active	3. High Active
No activity is reported	3 or more days of vigorous-intensity activity of at least 20 minutes per day	Vigorous-intensity activity on at least 3 days and accumulating at least 1500 MET-minutes/week
OR	OR	OR
Some activity is reported but not enough to meet Categories 2 or 3	5 or more days of moderate-intensity activity and/or walking of at least 30 minutes per day	7 or more days of any combination of walking, moderate- or vigorous-intensity activities accumulating at least 3000 MET-minutes/week
	OR	
	5 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum of at least 600 MET-min/week	

Because a high proportion of our participants were categorised as high active (54%) using this classification system, the median value of the high active group was used to dichotomise this category into two subcategories: high active and very high active. Physical activity data from the IPAQ-L are therefore be presented in four ways:

1. Categorically – low, moderate, high, very high
2. Continuously by time spent (minutes) at each intensity – walking, moderate, vigorous
3. Continuously by time (minutes) and energy (METs) spent in each domain – leisure, occupational, commuting, household/yard
4. Continuously by total physical activity – total time (minutes) and total energy expenditure (METs)

Time spent in sedentary behaviours (television viewing, computer usage, sitting) was estimated from the self-reported questionnaire and treated both as a continuous variable and as a categorical variable. There are currently no public health recommendations for time spent in sedentary behaviours in adults. Categories were therefore developed that were considered practical, interpretable and amenable to public health guidelines (as described in Chapter 4). Sitting was categorised as <20 hours/week, 20-40 hours/week, 40-60 hours/week, or >60 hours/week. Television viewing was categorised as <1 hour/day, 1-2 hours/day, 2-3 hours/day or >3 hours/day. Computer use was categorised as <10 hours/week, 10-20 hours/week, 20-30 hours/week, and >30 hours/week. In some analyses, tertiles of physical activity or sedentary behaviour are used to determine categories.

Both cardiorespiratory fitness measures were treated continuously and were also split into thirds and quarters, depending on the analysis being undertaken. The lower thirds or quarters represent the lowest levels of fitness while the higher thirds or quarters represent the highest levels of fitness.

Analyses

Chi-square tests were used to determine whether significant differences existed between the baseline sociodemographic characteristics of those who participated at follow-up and those who did not. Analysis-of-variance (ANOVA) was used to compare the baseline physical and behavioural characteristics of participants and non-participants, where the assumption of equal variances was met (for continuous variables). If this assumption was not met, the Kruskal-Wallis equality of populations rank test was used to compare differences. Categorical variables were analysed using chi-square tests. Those who provided data in the CDAH follow-up study during 2006 were excluded from these analyses. Those participants who were aged 7 or 8 years at baseline were excluded from all analyses because they did not provide any sociodemographic or physical activity data as children.

Tracking was assessed using a variety of methods, described separately for each measure below.

<u>Adiposity Measures</u>

Age- and sex-stratified Pearson correlation coefficients were calculated to examine the relationship between child and adult values of BMI and waist circumference. Both child and adult values were ranked within one-year age- and sex-specific strata prior to calculating the correlation coefficients. For the childhood data, rankings were determined from within the entire ASHFS 1985 sample (i.e. rankings were not limited to those with follow-up data only). Children were then classified as healthy weight or overweight using internationally accepted age- and sex-specific BMI cutpoints (Cole, Bellizzi et al. 2000), while adults were classified as healthy weight, overweight or obese using the internationally accepted cutpoints of BMI≥25kg/m^2 but <30kg/m^2 (overweight) and BMI≥30kg/m^2 (obese). Waist circumference was also used to classify adults with abdominal overweight (≥94 cm but <102 cm in males; ≥80cm but <88cm in females) or abdominal obesity (≥102cm in males and ≥88cm in females). The proportion of participants in each category from childhood to adulthood was calculated.

Population attributable fractions (PAFs) for the proportion of adult overweight attributable to childhood overweight were obtained from adjusted relative risks calculated from log binomial regression models, adjusted for age, childhood sociodemographic status, occupation, highest level of education, and in males, language spoken at home as a child and marital status; and in females, childhood smoking and number of children. The formula $PAF=p(r-1)/[1+p(r-1)]$ was used, where p is the probability of exposure to the risk factor and r is the relative risk. In this analysis, p is the probability that the individual was overweight as a child. To obtain 95% confidence intervals on the PAFs, the probabilities $P[PAF<L]=0.025$ and $P[PAF>U]=0.975$ were estimated (Benichou and Gail 1990). This was done assuming that the log of the relative risks had a normal distribution that was estimated from the log binomial model. The above probabilities were then integrated over all possible values of p, the exposure level, assuming it had a normal distribution with mean given by the exposure level estimated from the data using numerical integration.

BMI and waist circumference data were categorised into fifths. A log binomial model was used to calculate the relative risk of being a healthy weight versus overweight in adulthood, based on childhood fifth. The adult categories for BMI and waist circumference were based on the definitions for overweight described above. Relative risks and 95% confidence intervals are presented stratified by sex and school level.

Physical Activity Measures

Age group- and sex-stratified Pearson correlation coefficients were calculated to examine the relationship between child physical activity values and adult physical activity and sedentary behaviour variables. Both child and adult values were ranked within one-year age- and sex-specific strata prior to calculating the correlation coefficients. For the childhood data, rankings were determined from within the entire ASHFS 1985 sample (i.e. rankings were not limited to those with follow-up data only).

The proportion of participants remaining in each category of physical activity or inactivity from childhood to adulthood was calculated. These categories were the groupings developed in the cross-sectional chapters (Chapters 3 and 4). For children, each physical activity variable was categorised as follows: extracurricular sport (0-1 sports, 2 sports, 3 sports or 4+ sports); school sport (<30mins/week, 30-59mins/week, 60-89mins/week, 90+mins/week); school physical education (<30mins/week, 30-59mins/week, 60-89mins/week, 90+mins/week); active commuting to and from school (<30mins/week, 30-59mins/week, 60-89mins/week, 90+mins/week); non-organised physical activity (<60mins/week, 60-149mins/week, 150-299mins/week, 300+mins/week); and total physical activity (<3hrs/week, 3-6hrs/week, 6-9hrs/week, 9+hrs/week). For adults, the physical activity and sedentary behaviour variables were categorised as follows: daily weekly self-reported physical activity (low, moderate, high(lower), high(upper)); television viewing (<1hr/day, 1-2hrs/day, 2-3hrs/day, 3+hrs/day); sitting (<20hrs/week, 20-40hrs/week, 40-60hrs/wekk, 60+hrs/week); and computer usage

(<10hrs/week, 10-20hrs/week, 20-30hrs/week, 30+hrs/week). Chi-squared tests were used to determine whether differences in proportions were significantly different across categories.

Cardiorespiratory Fitness Measures

Age- and sex-stratified Pearson correlation coefficients were calculated to examine the relationship between child cardiorespiratory fitness values and adult cardiorespiratory fitness values. Both child and adult values were ranked within one-year age- and sex-specific strata prior to calculating the correlation coefficients. For the childhood data, rankings were determined from within the entire ASHFS 1985 sample (i.e. rankings were not limited to those with follow-up data only).

The proportion of participants remaining in each third of cardiorespiratory fitness from childhood to adulthood was calculated. Thirds were calculated using data from the entire ASHFS 1985 sample, rather than just restricting to participants with follow-up data. Chi-squared tests were used to determine whether differences in proportions were significantly different across thirds. Again, because two measures of cardiorespiratory fitness were collected in children, the associations of both of these measures with adult cardiorespiratory fitness are presented.

Log binomial regression was used to estimate the likelihood of being in the top third of cardiorespiratory fitness in adulthood, according to the third of cardiorespiratory fitness as a child. Results are presented as relative risks unadjusted, adjusted for sociodemographic factors in adulthood, and additionally adjusted for sociodemographic factors in childhood.

5.5 Characteristics of Participants

The baseline characteristics of participants who did not participate in any follow-up are compared with those who provided data at follow-up (Tables 55, 56 and 57). Some differences were noted. A greater proportion of males who attended independent schools participated in follow-up, but no difference in school type was noted for females. However, fewer females from the lowest area-level SES group participated in follow-up, and fewer females born outside Australia or who spoke a language other than English at home participated in follow-up. While some significant differences were noted between participants and non- participants for average height (males only) and BMI and waist girth (females only), the magnitude of these differences was small. There was no significant difference in weekly physical activity or yearly extracurricular sport participation reported by participants and non-participants. Additionally, a greater proportion of male and female participants reported at baseline that neither parent smoked cigarettes. No differences were noted in baseline smoking, alcohol consumption or parental physical activity.

Table 55: Baseline sociodemographic characteristics of participants & non-participants in the CDAH follow-up study, by sex

Sociodemographic Characteristics	Males		p	Females		p
	Non-Participants % (n)	Participants % (n)		Non-Participants % (n)	Participants % (n)	
School type % (n)						
Government	75.7 (1,638)	70.2 (558)	<0.01	74.1 (1,395)	76.4 (591)	0.40
Catholic	19.3 (418)	20.8 (165)		21.7 (409)	19.4 (150)	
Independent	5.0 (109)	9.1 (72)		4.1 (78)	4.3 (33)	
SEIFA[a] % (n)						
High	21.8 (465)	25.3 (196)	0.26	22.5 (415)	26.1 (199)	<0.05
Medium-high	29.2 (621)	27.7 (214)		28.5 (526)	28.3 (216)	
Medium-low	39.2 (835)	37.3 (289)		38.8 (716)	38.8 (296)	
Low	9.8 (209)	9.7 (75)		10.3 (190)	6.8 (52)	
COB % (n)						
Australia	92.1 (1,983)	92.7 (734)	0.58	89.9 (1,686)	94.6 (731)	<0.01
Outside Australia	7.9 (171)	7.3 (58)		10.1 (190)	5.4 (42)	
Language at home % (n)						
English	86.9 (1,874)	86.9 (689)	0.98	85.3 (1,601)	90.1 (697)	<0.01
Other than English	13.1 (282)	13.1 (104)		14.7 (276)	10.0 (77)	

[a] SEIFA: Socioeconomic Index for Areas

Table 56: Baseline physical & behavioural characteristics (continuous variables) of participants & non-participants in the CDAH follow-up study, by sex

Physical & Behavioural Characteristics	Males		p	Females		p
	Non-participants	Participants		Non-participants	Participants	
	Mean (SD)			Mean (SD)		
Age (years)	11.9 (2.0)	12.0 (2.0)	0.42	11.9 (2.0)	11.8 (2.0)	0.16
Height (cm)	151.8 (13.9)	153.1 (13.7)	<0.05	150.0 (11.5)	150.4 (11.8)	0.41
Weight (kg)	44.0 (12.9)	44.2 (12.7)	0.64	43.4 (11.5)	42.8 (11.1)	0.20
BMI (kgm/m^2)	18.7 (2.9)	18.5 (2.7)	0.36[a]	19.0 (3.0)	18.6 (2.8)	<0.05[a]
Waist (cm)	66.8 (8.9)	66.4 (7.7)	0.80[a]	64.9 (8.1)	63.5 (7.5)	<0.01
	Median (IQR)			Median (IQR)		
Total PA (mins)	360 (200, 630)	330 (195, 580)	0.13[a]	280 (160, 480)	300 (165, 520)	0.18[a]
School Sport (mins)	50 (0, 96)	50 (0, 100)	0.94[a]	40 (0, 90)	45 (0, 90)	0.41[a]
School PE (mins)	60 (0, 100)	53 (0, 90)	0.08[a]	60 (0, 90)	60 (0, 90)	0.93[a]
Active Transport (mins)	25 (0, 75)	20 (0, 70)	0.10[a]	15 (0, 75)	20 (0, 75)	0.90[a]
Non-Organised PA (mins)	150 (15, 360)	150 (30, 360)	0.83[a]	90 (0, 260)	110 (15, 270)	0.09[a]
Yearly Extracurricular Sport (n)	2 (2, 4)	2 (2, 4)	0.85[a]	2 (1, 3)	2 (1, 3)	0.30[a]

[a] p-values derived from Kruskal-Wallis equality of populations rank test

Table 57: Baseline physical & behavioural characteristics (categorical variables) of participants & non-participants in the CDAH follow-up study, by sex

Physical & Behavioural Characteristics	Males		p	Females		p
	Non-participants	Participants		Non-participants	Participants	
Weight Status % (n)						
Healthy Weight	88.0 (1,901)	90.6 (720)	0.70	85.4 (1,608)	90.7 (701)	<0.01
Overweight/Obese	12.0 (260)	9.4 (75)		14.6 (274)	9.3 (72)	
Smoking % (n)						
Never	52.0 (1,121)	55.4 (439)	0.09	59.1 (1,108)	58.6 (453)	0.93
A few puffs	24.9 (538)	26.7 (212)		21.0 (393)	22.0 (170)	
<10 ever	7.7 (166)	7.3 (58)		6.5 (122)	7.1 (55)	
>10 ever	15.4 (333)	10.6 (84)		13.5 (253)	12.3 (95)	
Parental Smoking % (n)						
Neither smoke	45.0 (965)	60.3 (478)	<0.01	46.9 (879)	55.9 (430)	<0.01
Both smoke	18.9 (405)	11.5 (91)		17.6 (331)	14.4 (111)	
Mum only smokes	18.9 (281)	7.7 (61)		14.5 (272)	10.9 (84)	
Dad only smokes	23.0 (494)	20.6 (163)		21.0 (394)	18.7 (144)	
Parental PA % (n)						
Both active	18.6 (371)	18.3 (135)	0.79	21.1 (365)	21.2 (155)	0.96
Mum active only	17.4 (347)	16.9 (125)		19.1 (330)	18.2 (133)	
Dad active only	20.4 (406)	22.2 (164)		18.9 (327)	19.5 (142)	
Both inactive	43.6 (867)	42.6 (315)		40.9 (708)	41.1 (300)	

5.6 Tracking of Adiposity Measures

BMI and waist circumference tracked at moderate to high levels from all ages in childhood to adulthood in both males and females (Figures 29 and 30) (for values, see Appendix 15, Table 32). Tracking of BMI was relatively consistent across all ages in females, although tended to be weaker in the oldest males. For waist circumference, tracking was relatively consistent across all ages in females, while for males tracking was marginally weaker in the youngest and oldest participants.

Figure 29: Correlation between childhood BMI & adulthood BMI for participants in the CDAH follow-up study, by sex & age

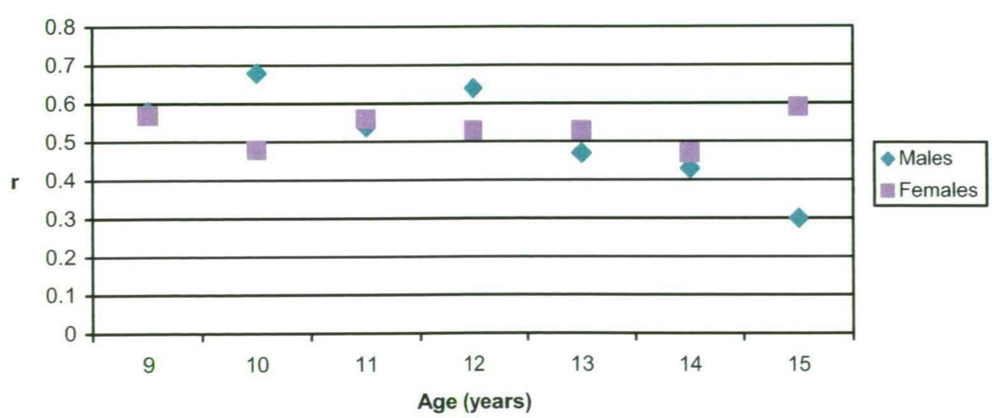
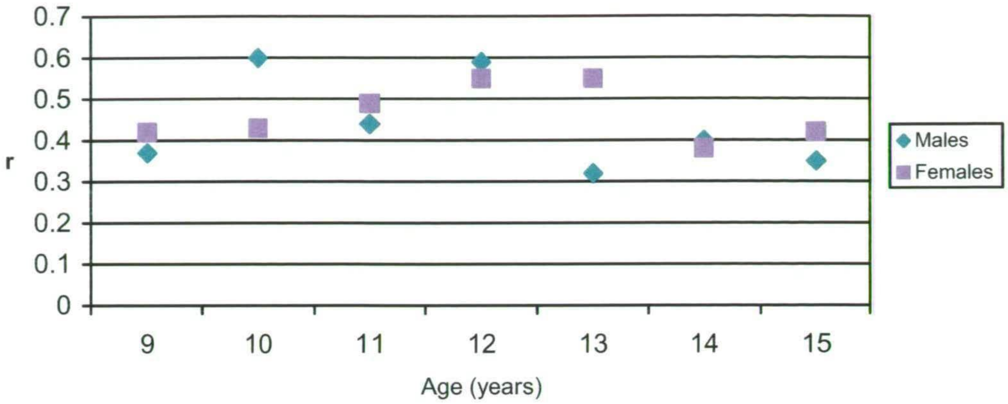


Figure 30: Correlation between childhood waist circumference & adulthood waist circumference for participants in the CDAH follow-up study, by sex & age



Strikingly, less than half of the healthy weight boys and only two thirds of the healthy weight girls remained healthy weight as adults (Table 58). While most overweight children remained overweight as adults, a small proportion became healthy weight adults. This was more evident in females than males, although these participants were in the minority. Using waist circumference to define overweight in adulthood, a greater proportion of males were classified as healthy weight, and a correspondingly smaller proportion was overweight (Appendix 15, Table 33). In addition, a greater proportion of overweight boys were classified as healthy weight adults when using waist circumference in adulthood to define healthy weight. This different definition also resulted in a smaller proportion of women classified as overweight.

Table 58: Weight status of children according to their adult weight status for participants in the CDAH follow-up study, by sex

Childhood Weight Status	**Adulthood Weight Status**			
	Healthy Weight (BMI<25kg/m^2)		**Overweight (BMI≥25kg/m^2)[b]**	
	n	%	n	%
Males				
Healthy Weight[a]	363	41.1	521	58.9
Overweight	4	4.1	94	95.9
Females				
Healthy Weight[a]	574	65.5	303	34.6
Overweight	14	14.9	80	85.1

[a] Healthy weight defined as a BMI less than the IOTF age & sex-specific cutpoints for children

While most healthy weight adults were healthy weight as children, a large proportion of overweight adults were also healthy weight as children (Table 59), highlighting the importance of early obesity prevention strategies. This finding also highlights the transition from childhood and early adolescence into late adolescence and early adulthood, where the development of overweight appears to occur. This is a period of life marked with many significant transitions but is rarely explored as a key time for intervention. Similar findings were observed when using waist circumference to define weight status in adulthood (Appendix 15, Table 34).

Table 59: Weight status of adults according to their weight status as a child for participants in the CDAH follow-up study, by sex

Adult Weight Status	Childhood Weight Status: Healthy Weight n	%	Overweight[b] n	%
Males				
Healthy Weight	363	98.9	4	1.1
Overweight[a]	521	84.7	94	15.3
Females				
Healthy Weight	574	97.6	14	2.4
Overweight[a]	303	79.1	80	20.9

[a] Overweight defined as BMI ≥25kg/m^2
[b] Overweight defined as a BMI greater than the IOTF age & sex-specific cutpoints for overweight in children (Cole, Bellizzi et al. 2000)

The findings suggest that the majority of overweight adults were actually healthy weight children. While overweight persists well from childhood to adulthood, only a small proportion of adult overweight could be explained by childhood overweight. In fact, the proportion of adult overweight attributable to childhood overweight was 6.8% (95% CI: 4.6-9.6) and 15.6% (95% CI: 11.1-20.7) for males and females, respectively. This observation provides further justification for investigating factors associated with the "success" of maintaining a healthy weight from childhood to adulthood. These factors will be further explored in the next chapter.

Being in the highest two BMI fifths in childhood significantly reduced the likelihood of being a healthy weight adult across all ages in childhood and in both males and females (Tables 60 and 61). These associations remained significant after adjusting for childhood and adult sociodemographic factors, which had minimal impact on the associations. In general, compared with being in the lowest BMI fifth, even those in the second lowest fifth (quintile 2) had a significantly reduced likelihood of being a healthy weight adult, a trend that continued with increasing childhood BMI fifths. These trends were stronger in boys than girls. The same analyses were conducted for waist circumference, with very similar results (Appendix 15, Tables 35 and 36).

Table 60: Relative risk (RR) of being a healthy weight adult based on childhood BMI fifth in males in the CDAH follow-up study, by age group

Child Age & BMI Quintile	**Healthy Weight %**	**(n/N)**	**RR**	**(95% CI)**	**Adj. RR[a]**	**(95% CI)**	**Adj. RR[b]**	**(95% CI)**
9-11 years								
Q1	70.7	(53/75)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Q2	63.5	(54/85)	0.90	(0.72-1.12)	0.83	(0.66-1.05)	**0.78**	**(0.62-0.98)**
Q3	34.3	(25/73)	**0.48**	**(0.34-0.69)**	**0.41**	**(0.28-0.60)**	**0.43**	**(0.30-0.63)**
Q4	16.9	(12/71)	**0.24**	**(0.14-0.41)**	**0.23**	**(0.13-0.41)**	**0.21**	**(0.11-0.38)**
Q5	23.8	(5/21)	**0.13**	**(0.06-0.31)**	**0.13**	**(0.05-0.33)**	**0.13**	**(0.05-0.34)**
12-13 years								
Q1	71.2	(37/52)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Q2	40.0	(16/40)	**0.56**	**(0.37-0.85)**	**0.56**	**(0.37-0.87)**	**0.48**	**(0.32-0.73)**
Q3	21.3	(10/47)	**0.30**	**(0.17-0.53)**	**0.26**	**(0.13-0.49)**	**0.22**	**(0.12-0.40)**
Q4	13.3	(6/45)	**0.19**	**(0.09-0.40)**	**0.18**	**(0.08-0.38)**	**0.15**	**(0.07-0.33)**
Q5	5.9	(1/17)	**0.08**	**(0.02-0.30)**	**0.08**	**(0.02-0.32)**	**0.07**	**(0.02-0.26)**
14-15 years								
Q1	57.5	(23/40)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Q2	31.1	(14/45)	**0.54**	**(0.32-0.90)**	**0.47**	**(0.26-0.85)**	**0.43**	**(0.23-0.77)**
Q3	30.0	(15/50)	**0.52**	**(0.32-0.86)**	**0.46**	**(0.28-0.75)**	**0.48**	**(0.30-0.77)**
Q4	22.0	(11/50)	**0.38**	**(0.21-0.69)**	**0.40**	**(0.21-0.76)**	**0.40**	**(0.26-0.61)**
Q5	4.6	(1/22)	**0.11**	**(0.04-0.34)**	**0.14**	**(0.04-0.42)**	**0.14**	**(0.05-0.43)**

[a] Adjusted for occupation, highest level of education, marital status
[b] Adjusted for all the above plus childhood SES & language spoken at home as a child

Table 61: Relative risk (RR) of being a healthy weight adult based on childhood BMI fifth in females in the CDAH follow-up study, by age group

Child Age & BMI Quintile	**Healthy Weight %**	**(n/N)**	**RR**	**(95% CI)**	**Adj. RR[a]**	**(95% CI)**	**Adj. RR[b]**	**(95% CI)**
9-11 years								
Q1	88.2	(60/68)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Q2	76.4	(55/72)	0.87	(0.41-1.01)	**0.80**	**(0.69-0.94)**	**0.72**	**(0.58-0.91)**
Q3	66.7	(52/78)	**0.76**	**(0.63-0.90)**	**0.74**	**(0.62-0.88)**	**0.69**	**(0.55-0.85)**
Q4	36.2	(25/69)	**0.41**	**(0.30-0.57)**	**0.40**	**(0.28-0.57)**	**0.36**	**(0.25-0.53)**
Q5	47.6	(10/21)	**0.33**	**(0.22-0.50)**	**0.36**	**(0.24-0.55)**	**0.33**	**(0.21-0.50)**
12-13 years								
Q1	82.0	(41/50)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Q2	79.5	(31/39)	0.97	(0.79-1.19)	1.00	(0.80-1.25)	0.82	(0.62-1.08)
Q3	76.3	(29/38)	0.93	(0.75-1.16)	0.95	(0.74-1.22)	0.84	(0.62-1.13)
Q4	52.2	(24/46)	**0.64**	**(0.47-0.86)**	**0.67**	**(0.49-0.93)**	**0.54**	**(0.37-0.78)**
Q5	36.4	(4/11)	**0.25**	**(0.12-0.52)**	**0.33**	**(0.16-0.67)**	**0.31**	**(0.15-0.63)**
14-15 years								
Q1	85.7	(42/49)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Q2	67.4	(29/43)	0.79	(0.62-1.00)	**0.62**	**(0.45-0.86)**	**0.58**	**(0.40-0.83)**
Q3	51.1	(24/47)	**0.60**	**(0.44-0.81)**	**0.51**	**(0.36-0.73)**	**0.44**	**(0.29-0.67)**
Q4	35.4	(17/48)	**0.41**	**(0.28-0.62)**	**0.34**	**(0.21-0.55)**	**0.28**	**(0.18-0.44)**
Q5	31.3	(5/16)	**0.18**	**(0.08-0.41)**	**0.14**	**(0.06-0.33)**	**0.15**	**(0.06-0.35)**

[a] Adjusted for occupation, highest level of education, & number of children
[b] Adjusted for all the above plus childhood SES & smoking

5.7 Tracking of Physical Activity

A description of child and adult levels of participation in various physical activities was presented in Chapters 3 and 4, respectively. The following section examines the relationship between child and adult physical activity at two points in time.

There were some weak correlations between some domains of childhood physical activity and self-reported time or energy spent in physical activity in adulthood (Table 62). School physical education in secondary school-aged males and females was significantly correlated with self-reported time and energy spent in past week physical activity in adults, and extracurricular sport participation in secondary school-aged females was significantly correlated with self-reported time and energy spent in past week physical activity.

Table 62: Correlation[a] between child & adult self-reported physical activity in the CDAH follow-up study, by sex & baseline school level

Child PA Measure	Self-Reported Weekly PA (mins)		Self-Reported Weekly PA (METs)	
	Males	Females	Males	Females
Total PA (mins)				
Primary	0.09	-0.05	0.09	-0.04
Secondary	0.03	0.07	0.04	0.08
School Sport (mins)				
Primary	-0.02	-0.06	-0.02	-0.04
Secondary	0.08	-0.06	0.09	-0.06
School PE (mins)				
Primary	0.02	0.01	0.02	0.02
Secondary	0.10*	0.21**	0.11*	0.21**
Active Commuting (mins)				
Primary	0.03	-0.03	0.02	-0.03
Secondary	0.00	0.05	0.00	0.05
Non-organised PA (mins)				
Primary	0.02	-0.04	0.02	-0.03
Secondary	-0.05	0.08	-0.05	0.09*
Extracurricular Sport (n)				
Primary	0.04	-0.03	0.03	-0.02
Secondary	0.02	0.13**	0.02	0.13**

[a] Values are Pearson correlation coefficients on age- & sex-specific ranked data
**p<0.01 *p<0.05

There were some weak but significant correlations between some types of self-reported childhood physical activity and the intensity of self-reported physical activity in adulthood (Table 63). These were noted between school physical education again in secondary school-aged females and adult levels of walking, moderate and vigorous physical activity. A similar observation was noted between school physical education in secondary school-aged males and moderate and vigorous physical activity as adults. Additionally, participation in extracurricular sport in secondary school-aged females was significantly correlated with adult walking and vigorous physical activity.

Table 63: Correlation[a] between childhood physical activity & intensity of self-reported physical activity in adulthood in the CDAH follow-up study, by sex & baseline school level

Baseline PA & School Level	Walking PA (mins)		Moderate PA (mins)		Vigorous PA (mins)	
	Males	Females	Males	Females	Males	Females
Total PA (mins)						
Primary	0.11*	-0.01	0.02	0.01	0.08	-0.00
Secondary	0.02	0.04	0.03	0.05	0.08	0.10*
School Sport (mins)						
Primary	-0.03	-0.05	0.00	-0.02	-0.02	-0.02
Secondary	0.09*	0.01	0.01	-0.11*	0.10*	-0.04
School PE (mins)						
Primary	0.01	0.01	-0.02	-0.01	0.00	0.02
Secondary	0.04	0.17**	0.10*	0.16**	0.10*	0.13**
Active Transport (mins)						
Primary	0.01	-0.00	0.04	-0.01	-0.00	-0.02
Secondary	0.06	0.11*	-0.02	0.06	-0.00	0.10*
Non-organised PA (mins)						
Primary	0.04	-0.01	-0.03	0.01	0.05	0.04
Secondary	-0.04	0.02	-0.03	0.07	-0.00	0.10*
Extracurricular Sport (n)						
Primary	0.10*	-0.02	0.05	-0.02	0.00	0.05
Secondary	0.06	0.11*	-0.02	0.07	0.05	0.14**

[a]Values are Pearson correlation coefficients on age- & sex-specific ranked data
**p<0.01 *p<0.05

When adult physical activity was assessed by domain of activity, some weak but significant correlations with childhood physical activity was noted (Table 64). These correlations differed by domain, sex and school level, but some trends were evident. In primary-school aged males, total self-reported physical activity was significantly correlated with adult leisure time activity and active commuting, and non-organised physical activity and extracurricular sport were correlated with adult leisure time physical activity. School physical education in secondary school-aged males was correlated with adult active commuting. For secondary-school aged females, school physical education was correlated with adult leisure time physical activity, occupational physical activity and household and yard physical activity. Active commuting for females of this school level was also correlated with adult active commuting and household and yard physical activity. Additionally, non-organised physical activity was correlated with leisure time physical activity in adulthood for this group.

Table 64: Correlation[a] between childhood physical activity & domains of physical activity in the CDAH follow-up study, by sex & baseline school level

Child PA Measure	Leisure Time PA (mins)		Occupational PA (mins)		Commuting PA (mins)		Household/Yard PA (mins)	
	Males	**Females**	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**
Total PA (mins)								
Primary	0.15**	0.01	0.03	-0.05	0.11*	0.09	0.05	-0.00
Secondary	0.04	0.12*	0.00	0.06	0.06	-0.01	0.08	0.01
School Sport (mins)								
Primary	0.06	-0.03	-0.04	-0.03	0.06	-0.00	0.03	-0.02
Secondary	0.04	0.03	0.07	-0.02	0.09	-0.02	-0.03	-0.09
School PE (mins)								
Primary	0.09	-0.04	0.01	-0.02	0.00	0.05	-0.09	-0.01
Secondary	0.06	0.10*	0.05	0.18**	0.11**	0.01	0.05	0.11*
Active Commuting (mins)								
Primary	-0.03	0.03	0.05	-0.04	-0.04	0.00	-0.00	-0.02
Secondary	0.08	0.07	0.01	0.01	-0.03	0.12*	0.00	0.09*
Non-organised PA (mins)								
Primary	0.17**	0.05	-0.05	-0.05	0.09	0.05	0.03	0.01
Secondary	-0.03	0.10*	-0.05	0.03	0.01	0.02	0.05	0.02
Extracurricular Sport (n)								
Primary	0.13*	0.07	0.01	-0.03	0.13**	0.02	0.02	0.04
Secondary	0.09	0.05	-0.00	0.12	0.08	0.03	-0.03	0.05

[a] Values are Pearson correlation coefficients on age- & sex-specific ranked data
**p<0.01 *p<0.05

There was some correlation between childhood measures of physical activity and self-reported sedentary behaviours in adulthood; however some of these were not in the expected direction (Table 65).

Table 65: Correlation[a] between self-reported childhood physical activity & adult sedentary behaviours in the CDAH follow-up study, by sex & baseline school level

Child PA Measure	TV Viewing (hrs/day)		Computer Use (hrs/week)		Sitting(hrs/week)	
	Males	Females	Males	Females	Males	Females
Total PA (mins)						
Primary	-0.02	-0.10*	-0.05	-0.02	-0.11*	0.02
Secondary	0.02	-0.03	0.01	-0.03	0.00	0.03
School Sport (mins)						
Primary	-0.02	-0.07	0.02	0.01	-0.01	0.02
Secondary	0.01	-0.04	-0.07	-0.01	-0.06	-0.03
School PE (mins)						
Primary	0.02	-0.01	-0.01	-0.04	-0.01	-0.03
Secondary	0.09*	0.03	0.10*	-0.05	-0.01	0.00
Active Commuting (mins)						
Primary	0.11*	-0.03	0.11*	-0.03	-0.07	0.01
Secondary	-0.01	0.08	-0.01	0.08	0.07	0.18**
Non-organised PA (mins)						
Primary	-0.05	-0.07	0.01	-0.00	-0.07	0.06
Secondary	-0.02	-0.05	-0.01	-0.02	0.01	-0.03
Extracurricular Sport (n)						
Primary	-0.02	0.05	-0.03	0.08	-0.04	0.05
Secondary	-0.04	-0.01	-0.01	-0.02	-0.06	-0.04

[a]Values are Pearson correlation coefficients on age- & sex-specific ranked data
**p<0.01 *p<0.05

While the correlations observed between child and adult physical activity were weak in general, there were some consistent statistically significant associations. For secondary school-aged females, baseline physical activity was correlated with adult physical activity, particularly school physical education, school sport and extracurricular sport. The strongest correlation seen for secondary-school aged females was between baseline school physical education and adult total physical activity (time and energy), suggesting that participation in physical education at school may be predictive of adult physical activity. Similarly, for those males who were secondary-school aged at baseline, school physical education and school sport were correlated with adult physical activity. Again, this may suggest that adult physical activity patterns may be becoming established at this age. Significant correlations were also seen between total physical activity and yearly extracurricular sport in childhood, and adult walking, leisure time physical activity and active commuting, in males who were primary school-aged at baseline. In contrast, there was little correlation between baseline and follow-up physical activity for those females who were primary-school aged at baseline.

Unexpectedly, active commuting in childhood was positively correlated with television viewing and computer usage in males who were primary school-aged at baseline and with sitting in females who were secondary school-aged at baseline. In males who were secondary school-aged at baseline, school PE was positively correlated with television viewing and computer usage. It is however possible that these associations were confounded by factors in childhood such as proximity to school and provision of PE, or factors in adulthood such as occupation.

Interestingly, total physical activity at baseline was inversely correlated with sitting in males and television viewing in females who were primary school-aged at baseline.

When analysed categorically, there was little evidence to suggest that childhood physical activity was associated with adult physical activity (data not shown). There was no difference in the childhood physical activity of adults deemed low, moderate or high active based on self-reported activity. There was a suggestion of a weak association between some childhood physical activities and adult sedentary behaviours. Females who watched the least amount of television tended to be those who as children participated in the most non-organised physical activity, although associations were weak and not observed in males. Males who participated in the most total weekly physical activity as children were also those who did the least amount of sitting as adults, although no differences in sitting were noted amongst females. Both males and females who participated in the most school sport as children also used computers the least as adults, as did females who participated in the most school physical education.

The relative risk of being in the top third of adult physical activity was calculated for each of the four categories of total childhood physical activity (defined in Chapter 3). The youngest males in the highest childhood physical activity categories were more likely to be in the top third of physical activity as an adult than those in the lowest childhood physical activity category (Table 66). No clear trends were seen for 12-15 year old males, although there was a small increase in the likelihood of being in the top third of adult physical activity for 14-15 year old males in the highest childhood physical activity category. The most active of the oldest girls had an increased likelihood of being in the top third of physical activity as adults, although these findings were attenuated after adjustments for sociodemographic factors (Table 67). No other clear trends were evident for females aged 9-13 years.

Table 66: Relative risk (RR) of being in the top third of self-reported physical activity in adulthood based on self-reported childhood physical activity fifths in males in the CDAH follow-up study, by age group

Child Age & Weekly PA (hrs/wk)	Highest Adult PA Third %	(n/N)	RR	(95% CI)	Adj. RR[a]	(95% CI)	Adj. RR[b]	(95% CI)
9-11 years								
<3 hrs/wk	26.4	(29/110)	1.0	(ref)	1.0	(ref)	1.0	(ref)
3-6 hrs/wk	33.3	(40/120)	1.26	(0.85-1.89)	**1.42**	**(1.01-1.20)**	1.23	(0.95-1.58)
6-9 hrs/wk	35.1	(20/57	1.33	(0.83-2.13)	**1.45**	**(1.00-2.10)**	**1.35**	**(1.04-1.76)**
9+ hrs/wk	40.8	(31/76)	**1.55**	**(1.02-2.34)**	**1.72**	**(1.22-2.44)**	**1.60**	**(1.24-2.05)**
12-13 years								
<3 hrs/wk	46.7	(21/45)	1.0	(ref)	1.0	(ref)	1.0	(ref)
3-6 hrs/wk	43.0	(37/86)	0.92	(0.62-1.37)	0.85	(0.65-1.11)	0.96	(0.71-1.30)
6-9 hrs/wk	33.3	(12/36)	0.71	(0.41-1.25)	0.77	(0.50-1.17)	0.85	(0.53-1.37)
9+ hrs/wk	40.2	(33/82)	0.86	(0.57-1.30)	1.01	(0.78-1.30)	0.83	(0.60-1.13)
14-15 years								
<3 hrs/wk	26.3	(10/38)	1.0	(ref)	1.0	(ref)	1.0	(ref)
3-6 hrs/wk	21.7	(13/60)	0.82	(0.40-1.69)	0.91	(0.50-1.67)	0.92	(0.55-1.53)
6-9 hrs/wk	31.9	(15/47)	1.21	(0.62-2.39)	1.02	(0.58-1.77)	1.00	(0.75-1.35)
9+ hrs/wk	36.1	(35/97)	**1.37**	**(0.76-2.48)**	1.19	(0.74-1.92)	1.25	(0.90-1.74)

[a] Adjusted for occupation, highest level of education, marital status
[b] Adjusted for all the above plus childhood SES & language spoken at home as a child

Table 67: Relative risk (RR) of being in the top third of self-reported physical activity in adulthood based on childhood self-reported physical activity fifths in females in the CDAH follow-up study, by age group

Child Age & Weekly PA (hrs/wk)	Highest Adult PA Third %	(n/N)	RR	(95% CI)	Adj. RR[a]	(95% CI)	Adj. RR[b]	(95% CI)
9-11 years								
<3 hrs/wk	38.2	(52/136)	1.0	(ref)	1.0	(ref)	1.0	(ref)
3-6 hrs/wk	35.8	(53/148)	0.94	(0.69-1.27)	1.01	(0.79-1.29)	0.99	(0.73-1.34)
6-9 hrs/wk	33.9	(20/59)	0.89	(0.59-1.34)	0.91	(0.58-1.41)	0.93	(0.60-1.45)
9+ hrs/wk	29.6	(21/71)	0.77	(0.51-1.17)	0.89	(0.59-1.33)	0.83	(0.58-1.20)
12-13 years								
<3 hrs/wk	41.4	(24/58)	1.0	(ref)	1.0	(ref)	1.0	(ref)
3-6 hrs/wk	33.3	(20/60)	0.81	(0.50-1.29)	0.66	(0.43-1.00)	0.65	(0.42-1.00)
6-9 hrs/wk	41.4	(24/58)	1.00	(0.65-1.54)	0.77	(0.49-1.23)	0.77	(0.49-1.22)
9+ hrs/wk	37.5	(30/80)	0.91	(0.60-1.38)	0.94	(0.64-1.39)	0.88	(0.63-1.24)
14-15 years								
<3 hrs/wk	24.2	(15/62)	1.0	(ref)	1.0	(ref)	1.0	(ref)
3-6 hrs/wk	30.4	(28/92)	1.26	(0.73-2.15)	1.14	(0.67-1.96)	1.28	(0.73-2.25)
6-9 hrs/wk	41.7	(20/48)	1.72	(0.99-3.00)	1.46	(0.80-2.67)	1.63	(0.87-3.05)
9+ hrs/wk	45.2	(28/62)	**1.87**	**(1.11-3.14)**	1.63	(0.96-2.77)	1.56	(0.88-2.76)

[a] Adjusted for occupation, highest level of education, & number of children
[b] Adjusted for all the above plus childhood SES & smoking

5.8 Tracking of Cardiorespiratory Fitness

Cardiorespiratory fitness estimated in childhood was associated with the same measure of adult fitness in most participants (Table 68). While this association did not always reach statistical significance, it was approached (p=0.08 for 12-year old males and p=0.08 for 15-year old females).

Table 68: Correlation[a] between measures of cardiorespiratory fitness (PWC_{170}) in childhood & adulthood for participants in the CDAH follow-up study, by sex & baseline age

Baseline Age	Males		Females	
(years)	n	*r*	n	*r*
9	95	0.25*	94	0.29**
12	97	0.19	88	0.28**
15	83	0.35**	84	0.19

[a] Values are Pearson correlation coefficients on age- & sex-specific ranked data
**p<0.01 *p<0.05

The proportion of participants in each third of cardiorespiratory fitness at baseline and follow-up was examined to gain further understanding of the relationship between cardiorespiratory fitness from childhood into adulthood (Table 69). While there was much movement across tertiles, those participants in the lowest and highest thirds in childhood had a tendency to remain in the same third as adults. The associations were generally not statistically significant, but the small number of participants in each cell limited the statistical power.

Table 69: Proportion of participants remaining in the same third of cardiorespiratory fitness (PWC_{170}) in childhood & adulthood, by sex & age at baseline

Childhood Age	Adult Fitness Third					
& Fitness	Males			Females		
Third	Lowest Third	Middle Third	Highest Thir	Lowest Third	Middle Third	Highest Third
9 years						
Lowest Third	46.7 (14)	26.7 (8)	26.7 (8)	47.2 (17)	27.8 (10)	25.0 (9)
Middle Third	18.5 (5)	33.3 (9)	48.2 (13)	27.6 (8)	41.4 (12)	31.0 (9)
Highest Third	18.4 (7)	36.8 (14)	44.7 (17)	6.9 (2)	55.2 (16)	37.9 (11)
		chi2=8.5, p=0.08			chi2=13.0, p<0.05	
12 years						
Lowest Third	48.6 (17)	37.1 (13)	14.3 (5)	46.4 (13)	28.6 (8)	25.0 (7)
Middle Third	42.9 (15)	25.7 (9)	31.4 (11)	17.9 (5)	39.3 (11)	42.9 (12)
Highest Third	33.3 (9)	44.4 (12)	22.2 (6)	28.1 (9)	15.6 (5)	56.3 (18)
		chi2=4.7, p=0.32			chi2=10.4, p<0.05	
15 years						
Lowest Third	32.0 (8)	28.0 (7)	40.0 (10)	40.0 (10)	20.0 (5)	40.0 (10)
Middle Third	32.1 (9)	35.7 (10)	32.1 (9)	34.5 (10)	17.2 (5)	48.3 (14)
Highest Third	20.0 (6)	36.7 (11)	43.3 (13)	23.3 (7)	33.3 (10)	43.3 (13)
		chi2=1.9, p=0.76			chi2=3.3, p=0.51	

Being in the top third of cardiorespiratory fitness as a child increased the likelihood of being in the top third of cardiorespiratory fitness as an adult in both males and females and across all ages (Table 70). However, these associations only reached statistical significance in primary school-aged females after adjustment for sociodemographic characteristics, and primary school-aged males in the middle third of cardiorespiratory fitness had an increased likelihood of being in the top third of cardiorespiratory fitness as adults.

Table 70: Relative risk (RR) of being in the highest third of adult cardiorespiratory fitness[a] from childhood cardiorespiratory fitness[a] (PWC_{170}), by school level & sex in the CDAH follow-up study

Sex & Baseline School Level	% Highest Third	(n/N)	RR	(95% CI)	Adj. RR[a]	(95% CI)	Adj. RR[b]	(95% CI)
Males								
Primary								
Lowest Third	47.8	(22/46)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Middle Third	39.5	(15/38)	1.89	(0.98-3.67)	**2.04**	**(1.06-3.92)**	**2.36**	**(1.13-4.91)**
Highest Third	40.0	(16/40)	1.87	(0.97-3.60)	1.54	(0.81-2.94)	1.68	(0.87-3.27)
Secondary								
Lowest Third	37.5	(15/40)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Middle Third	33.3	(17/51)	1.15	(0.61-2.16)	1.21	(0.62-2.38)	1.33	(0.66-2.69)
Highest Third	36.8	(21/57)	1.38	(0.76-2.48)	1.59	(0.86-2.94)	1.50	(0.81-2.80)
Females								
Primary								
Lowest Third	75.5	(40/53)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Middle Third	65.1	(28/43)	1.33	(0.74-2.39)	1.07	(0.57-2.02)	1.13	(0.61-2.11)
Highest Third	54.8	(17/31)	1.72	(0.97-3.03)	1.66	(0.98-2.83)	**1.76**	**(1.06-2.91)**
Secondary								
Lowest Third	53.2	(25/47)	1.0		1.0	(ref)	1.0	(ref)
Middle Third	72.3	(34/47)	1.39	(0.81-2.38)	1.44	(0.86-2.40)	1.61	(0.98-2.65)
Highest Third	64.8	(35/54)	1.30	(0.77-2.19)	1.16	(0.67-2.00)	1.41	(0.87-2.30)

[a] Adjusted for lean body mass
[b] Adjusted for occupation, highest level of education, marital status (males), number of children (females)
[c] Adjusted for all the above plus childhood SES, language spoken at home as a child (males) & childhood smoking (females)

5.9 Discussion

This is the largest study in Australia and one of the largest in the world to prospectively examine tracking of adiposity, physical activity and cardiorespiratory fitness from childhood to adulthood. It is one of the first studies to examine tracking of weight status using recently established age- and sex-specific cutpoints for overweight in children and one of few studies that have additional adiposity data – waist circumference – at two time points. Few previous studies, and none in Australia, have had a large enough sample size to analyse results by sex and multiple age strata. This is important because as observed in the current study, the strength of the tracking varied with age and sex which has implications for public health interventions.

One of the most striking findings from this chapter was the relatively small proportion of healthy weight children who remained healthy weight as adults, particularly males. Only 40% of males and 65% of females who were healthy weight children remained healthy weight into adulthood. Looking at this from a different perspective, 85% and 80% of overweight men and women, respectively, were healthy weight children. Only a small proportion of overweight in adulthood could therefore be attributed to overweight in childhood, although the large majority of overweight children did become overweight or obese adults – only 4% of overweight boys and 15% of overweight girls became healthy weight adults. The findings suggest that while healthy weight children are much more likely to be healthy weight adults than overweight children, a large proportion of overweight adults were a healthy weight in childhood.

The proportion of healthy weight children who became overweight adults was higher in this study than previous studies. For instance, in the Northern Finland Birth Cohort (Laitinen, Power et al. 2001), 42% and 22% of normal weight boys and girls, respectively, became overweight or obese adults, compared with 60% and 35%, respectively, in the current study. It is likely that this is a function of the increasing prevalence of overweight and obesity in adult populations, which has been well documented in both Australia and most developed countries. It is also possible that it is a function of the different cutpoints used to define weight status in childhood. In the current study, recently developed age- and sex-specific cutpoints developed by the IOTF were used to define healthy weight and overweight, while previous studies have generally used population reference values.

While the proportion of healthy weight children who became overweight or obese adults was higher in the current study, the proportion of overweight children who remained overweight as adults was similar in the current study to that observed previously. The current study saw 85-95% of overweight children become overweight adults, marginally higher than that observed in the Northern Finland Birth Cohort study (64-88%) (Laitinen, Power et al. 2001) and the Muscatine Coronary Risk Factor Study (47.9-87.5%) (Clarke and Lauer 1993). The only study to use the IOTF childhood age- and sex-specific cutpoints to define weight status saw a marginally lower proportion of overweight children become overweight adults than the current study (76-86%) (Magarey, Daniels et al. 2003), an interesting finding because both this and the current study were Australian studies. These findings highlight the usefulness of the recently developed IOTF age- and sex-specific cutpoints to define weight status in children (Cole, Bellizzi et al. 2000), which enable direct comparisons between findings within Australia, internationally and over time. These findings also highlight the importance of childhood obesity prevention, given the consistently high proportion of overweight children who become overweight adults, irrespective of the country, definitions used, age at baseline and length of follow-up.

The continuous measures of adiposity – BMI and waist girth – tracked well from childhood to adulthood. Previous tracking studies assessing continuous measures of adiposity have observed similar findings to those observed in the current chapter. For BMI, correlation coefficients in the current study ranged from r=0.30 in 15 year old males to r=0.68 in 10 year old males. While the current study saw little trend across age groups, previous research has seen increasing tracking with increasing baseline age (Guo, Roche et al. 1994; Williams 2001; Freedman, Khan et al. 2005), although in the Muscatine study trends were not consistent (Clarke and Lauer 1993). Few studies have had the ability to additionally measure tracking of waist circumference, for which significant tracking was observed in the current study (correlation coefficients ranging from r=0.30-0.60). Again, no consistent trends were observed for increasing baseline age. The different methods of analysis and different measures of adiposity used in other studies make it difficult to compare results directly. However, similar coefficients were observed in those studies that used the same analytic methods and most have concluded similarly that moderate to high levels of tracking were present for the different for measures of adiposity. Another point to consider is the lack of variation in childhood BMI. Nearly 90% of children were deemed healthy weight using the IOTF age- and sex-specific cutpoints for overweight. It is possible that this lack of variation may have resulted in lower correlation coefficients than would have been seen if a sample of today's children were assessed, where overweight and obesity are more prevalent.

Weak tracking was observed for physical activity irrespective of the measure used, the sex of the participants, or baseline age. Previous research investigating tracking of physical activity from childhood to adulthood has observed mixed findings, and reviews have concluded that physical activity over this time period tracks at low to moderate levels (Malina 1996; Malina 2001). Many studies have used small sample sizes which limit the statistical power and the ability to draw firm conclusions about results. Smaller studies do not allow for detailed stratification, which can be useful for disentangling the effects of sex, age and sociodemographic characteristics. The difficulties associated with measuring physical activity, particularly in children, and different measures used at both time points, may contribute to the weak levels of tracking observed. In the current study, reliable and valid self-reported measures of physical activity were used at follow-up, but the reliability and validity of the childhood measures is less certain. However, there is reason to believe that the children in this study reported their physical activity reasonably reliably and accurately. First, the age of the children in this study was 9-15 years and it has been demonstrated that children over the age of 9 years can reliably and accurately report their physical activity (Sallis, Buono et al. 1993). Second, average responses to physical activity questions were within acceptable and expected ranges, for instance, median weekly time spent in school physical education per week was 60 minutes for primary school-aged children (i.e. one class per week) and 100 minutes for secondary school-aged children (i.e. 2 classes per week). Third, average values for physical activity questions showed similar trends to that seen in other studies. For instance, males reported higher mean values for all activities than girls, as consistently observed in previous research (Sallis, Prochaska et al. 2000). Additionally, time spent in total physical activity for boys increased with age, while in girls time spent in total physical activity increased to the age of 13 years, then decreased, similar to trends observed previously in young adolescent females (Aaron, Kriska et al. 1993; Kimm, Glynn et al. 2002).

Interestingly, a number of tracking studies observed that membership or participation in sports clubs and sports training increased the likelihood of participation in physical activity or sport as an adult (Glenmark, Hedberg et al. 1994; Barnekow-Bergkvist, Hedberg et al. 1996; Telama, Leskinen et al. 1996; Laitinen, Power et al. 2001; Trudeau, Laurencelle et al. 2004; Telama, Yang et al. 2006), a finding not observed in the current study. It is possible that participation in these extracurricular sports differentiates between those genuinely interested and active in sports, compared with those who simply participate as part of mandatory school sport or physical education. It is again possible that the insensitivity of sports participation measures in the current study underestimated associations and results in bias towards the null. Alternatively, cultural differences in the value placed on sport and differences in participation levels may explain the differences observed between this and other studies.

While weak tracking was observed for physical activity, cardiorespiratory fitness showed better evidence of tracking from childhood into adulthood. A weakness of some previous research is the use of different measures of cardiorespiratory fitness at baseline and follow-up to estimate tracking (Barnekow-Bergkvist, Hedberg et al. 1996; Boreham, Robson et al. 2004).This approach has some limitations because the different measures may estimate different components of fitness. For example, a field run requires participants to support their own weight load, while a cycle ergometer test relieves some of this load; therefore heavier children are disadvantaged in the field run. Interestingly, the two studies that used different measures of cardiorespiratory fitness at baseline and follow-up also observed the weakest relationship between fitness at the two time points. Studies that used the same measure of fitness at baseline and follow-up saw correlation coefficients of a similar magnitude to that observed in this chapter for the cycle ergometer test (Andersen and Haraldsdottir 1993; Twisk, Kemper et al. 2000; Campbell, Katzmarzyk et al. 2001; Trudeau, Shephard et al. 2003). In this study, only primary school-aged females in the highest third of cardiorespiratory fitness were more likely to be in the highest fitness third as adults. However, associations tended to be in the expected direction and many neared statistical significance, suggesting that the difference in findings is likely because of limited statistical power, with cell sizes ranging from 10 to 40 after stratification by gender, school level, fitness third in childhood and fitness third in adulthood.

Some researchers have expressed concern that when a large number of comparisons have been made, some significant findings may occur by chance (i.e. a type I error or false positive finding). Type I errors are statistically significant associations that occur only by chance . While it is possible to statistically adjust for multiple comparisons (i.e. a Bonferroni adjustment), Rothman (p.147-50) argues that the best approach for epidemiologists is to present findings of all analyses conducted as if they alone were the sole focus of the study, not just the statistically significant findings, so that readers can then make their own adjustments and interpretations based on the total number of tests conducted. Rothman also argues that making statistical adjustments for multiple comparisons increases the likelihood of Type II errors (false negative findings).The strength and consistency of the relationships seen in this chapter, particularly for the adiposity and fitness measures, provide additional confidence that the associations observed are real.

Measures of SES appeared to have little impact on the results. In analyses of BMI, waist circumference, weight status and cardiorespiratory fitness tracking, adjusting for socioeconomic factors generally strengthened associations marginally. In contrast, adjusting for socioeconomic factors in physical activity tracking analyses tended to marginally attenuate associations. It seems likely that the minimal influence of sociodemographic factors is likely due to significant changes in socioeconomic circumstances, body composition and physical activity behaviours over time. These changes combined with the possibility for imprecision in the measures potentially mask any influence that sociodemographic factors may have longitudinally.

The findings from this chapter highlight a number of key issues in the tracking of adiposity, physical activity and cardiorespiratory fitness. The strong relationship between child and adult adiposity has important public health implications. Being an overweight child significantly increased the risk of being an overweight adult. Similarly, healthy weight adults were much more likely to have been healthy weight children, but a large proportion of healthy weight children became overweight adults. Given the nearly identical proportion of children deemed overweight at each age from 9 to 15 years, this finding may suggest that the onset of overweight was likely to be in late adolescence or early adulthood, which may be key periods for the timing of overweight prevention strategies. The weak relationship observed between child and adult physical activity suggests that strategies to promote children's physical activity with the aim of developing good habits that carry through to adulthood may not be effective. While there is no dispute that participating in physical activity at any age has positive social, physical and mental health benefits, the findings of this and numerous previous studies suggest that childhood physical activity is only weakly related to adult physical activity. Even those children in the most active groups in the current study were unlikely to be the most active adults. Future interventions may be more successful if they are based on evidence that identifies key times and population subgroups where physical activity "drop-out" occurs most commonly.

5.10 Summary

What is already known?

- Adiposity measures appear to track well from childhood to adulthood
- Physical activity appears to track poorly from childhood to adulthood
- Cardiorespiratory fitness appears to track at moderate levels from childhood to adulthood
- Tracking of these factors has not previously been examined in a large contemporary sample of young Australians, who may differ to those examined previously in other countries because of temporal, social, behavioural & environmental differences

What has been done to learn more?

- 2,053 young Australian adults (aged 26-36 years) were surveyed as part of the Childhood Determinants of Adult Health (CDAH) follow-up study
- Participants completed a physical activity questionnaire in childhood, the IPAQ-L in adulthood, and had their fitness, height, weight and waist circumferences measured at both time points
- Correlation coefficients were calculated and log binomial regression was used to estimate the association between child and adult adiposity, physical activity and cardiorespiratory fitness

What were the key results?

- 41% of males and 66% of females who were healthy weight as children remained healthy weight as adults. 96% of males and 85% of females who were overweight as children remained overweight as adults. Those in the highest fifth of BMI as children were least likely to be healthy weight adults.
- The association between child and adult physical activity was weak and varied with age and measure of physical activity (males: r=0.03 to 0.09; females: r=-0.04 to 0.08). Some significant but weak associations were observed between physical activity in secondary school-aged children and adult physical activity, particularly in females.
- Tracking of cardiorespiratory fitness from childhood to adulthood was stronger and varied with age: r=0.19 to 0.35 in males and r=0.19 to 0.29 in females.

What does this study add?

- Tracking of adiposity, physical activity & cardiorespiratory fitness in this contemporary sample of young Australians appears similar to tracking in other populations
- The findings highlight the large proportion of individuals who appear to become overweight between childhood & adulthood, suggesting late adolescence & early adulthood may be key times for intervention

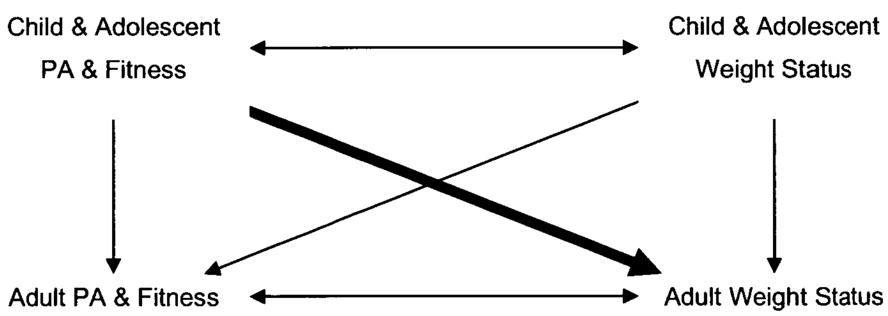
CHAPTER 6 – ARE ACTIVE, FIT CHILDREN MORE LIKELY TO MAINTAIN A HEALTHY WEIGHT FROM CHILDHOOD TO ADULTHOOD?

6.1 Introduction

In the previous chapter, tracking of adiposity measures, physical activity and cardiorespiratory fitness was examined. A high level of tracking of BMI and waist circumference was observed, as well as low levels of tracking for physical activity and moderate levels of cardiorespiratory fitness tracking.

In this chapter, the longitudinal association between physical activity, cardiorespiratory fitness and healthy weight maintenance is examined, as highlighted in Figure 31. While other studies have examined childhood predictors of adult overweight and obesity, there have been no published studies examining the predictors of maintaining a healthy weight from childhood through to adulthood, with a particular focus on the role of physical activity and cardiorespiratory fitness. Examining the factors that predict healthy weight maintenance from childhood through to adulthood may provide useful insights for the development of appropriate obesity prevention strategies.

Figure 31: Conceptual model of the relationships between physical activity, fitness & weight status from childhood & adolescence into adulthood



Adapted from Blair et al (1989)

Few studies have examined predictors of healthy weight maintenance, but there is more examining the predictors of obesity which provide useful insights. Parsons and colleagues undertook a systematic review of childhood predictors of adult obesity (Parsons, Power et al. 1999). The authors included in their review longitudinal observational studies of healthy children that included measurement of a risk factor in childhood (<18 years), and an outcome measure at least one year later; used any measure of fatness, leanness or change in fatness or leanness; and involved participants from industrialised countries. Studies that only measured fat distribution rather than overall fatness, those involving minority or special groups, and those that provided insufficient basic information (sample size, age of participants, sufficient definition of risk factor or outcome was lacking or not referenced to a previous publication) were excluded from the review. An electronic database search initially identified 22,359 studies for the review. After exclusion of irrelevant work (criteria outlined above), risk factors for obesity were grouped into seven categories (the number of longitudinal studies spanning childhood to adulthood is provided in parentheses): parental fatness and genetic factors (3 studies), social factors (30 studies), birth weight (7 studies), time or rate of maturation (22 studies), physical activity (4 studies), dietary factors (15 studies) and other behavioural or psychological factors (2 studies). The authors' main findings were:

- Children of obese parents were more likely to be obese as adults than children of healthy weight parents; however there is still debate about the relative contribution of genes and environment to the variation in fatness.
- Children from lower socioeconomic groups are more likely to become obese adults than children from higher socioeconomic groups. In females only, upward social mobility appears to be associated with a lower prevalence of overweight than downward social mobility. Family size, number of parents at home and child-care arrangements were factors identified as having limited research.
- Studies consistently demonstrated that a higher birth weight was associated with a higher adult BMI; however, when attempts were made to control for potential confounding factors, this relationship was less clear.
- There was a consistent relationship between early or rapid maturation and adult obesity. However, confounding factors such as parental fatness, SES, earlier fatness in childhood, or dietary and physical activity behaviours, were not well controlled for in these studies.
- The evidence for a relationship between childhood physical activity and obesity in adulthood was inconsistent, although suggestive of a protective effect of physical activity. Different measures of physical activity, different analytical methods and limited time spans make it difficult to make firm conclusions.
- Studies investigating the role of diet in childhood on adult obesity were limited, with follow-up into adulthood rare.
- There was a diverse range of studies that investigated behavioural and psychological factors, but few had common themes or examined mechanisms that may impact on fatness.

The most significant research gap identified by the authors was the lack of long-term follow-up data that covered the time period from childhood to adulthood. An additional area of research that the authors identified as neglected was the lack of data assessing factors that predict healthy weight maintenance, which they stipulate may or may not be the opposite of predictors of obesity. Healthy weight maintenance will be the focus of this chapter.

6.2 Literature Review

The following section provides a critical analysis of the literature surrounding the relationship between weight status, physical activity and cardiorespiratory fitness from childhood to adulthood. First, concepts associated with weight maintenance and healthy weight maintenance are introduced, followed by a discussion of studies of predictors of healthy weight maintenance. Investigations that have examined the relationship between physical activity and cardiorespiratory fitness in childhood and subsequent weight status in adulthood are reviewed, followed by an examination of reports that have assessed physical activity and cardiorespiratory fitness patterns from childhood to adulthood and their association with adult weight status.

6.2.1 Weight Maintenance

While many research interventions have examined maintenance of weight after weight loss, few studies have investigated weight maintenance without prior intervention or have attempted to define weight maintenance. A small number of studies have assessed weight maintenance, irrespective of baseline BMI. This type of analysis may include those who were already overweight or obese at baseline but who did not gain weight over the follow-up period. In this type of analysis, not gaining weight over the follow-up period is considered a healthier trend than gaining weight. Ball and colleagues assessed weight maintenance over four years in 8,726 young women aged 18-23 years at baseline (Ball, Brown et al. 2002). Weight maintenance was defined as a BMI at follow-up within 5% of baseline BMI. Forty four per cent of women were classified as weight maintainers, 41% gained more than 5% of their baseline weight, while 15% lost more than 5% of their baseline weight.

St Jeor and colleagues aimed to develop a definition of weight maintenance (St Jeor, Brunner et al. 1995). Over five years, 385 adults aged 20 years or more had their height, weight, three skinfolds, waist girth and hip girth measured annually. Participants were first classified as maintainers, gainers or losers based on a 5lb or greater change from baseline to year five. Second, a Fluctuation Index was developed to characterise weight change between each year of follow-up. The Fluctuation Index counts the number of years in which a subject's body weight changed 5lb or more. Participants were then True Maintainers if their five-year measure of weight was within 5lb of their baseline weight and whose weight did not fluctuate by more than 5lb between each year. Those whose five-year weight was within 5lb of their baseline measure but their weight fluctuated by more than 5lb in any one year were deemed End-Point

Maintainers. Participants' whose weight stayed within 5lb from year to year but whose endpoint weight was 5lb greater than their baseline weight were deemed Year-to-Year Maintainers, while those whose endpoint weight was 5lb greater than their baseline weight and whose weight fluctuated 5lb or more in at least one year interval were deemed Non-Maintainers.

Using these definitions, 19% of the sample was deemed True Maintainers, while 6% were deemed Year-to-Year Maintainers, 27% were End-Point Maintainers and 48% were Non-Maintainers. In addition to the complexity of this method, there is also a need for measures of weight on more than two occasions, limiting the usability of this definition in other studies. In a further, simpler, analysis of the same data, participants were classified as weight maintainers if their weight at five years remained within 5lb of baseline weight. Using this definition of weight maintenance, 46% of subjects were deemed maintainers (St Jeor, Brunner et al. 1997).

None of these definitions take into account weight status at baseline; that is, whether participants are healthy weight, overweight or obese to begin with. Taking baseline weight status into account allows for in-depth examination of weight status patterns and allows for comparison between those who remain healthy weight over time and those who become overweight or obese over time.

6.2.2 Healthy Weight Maintenance

To this author's knowledge, only one published study has assessed maintenance of healthy weight status. In their study of 165 married white couples, Davison and colleagues classified weight maintenance as a BMI<25kg/m^2 at baseline and follow-up weight within 5% of baseline weight (Davison and Birch 2004). Using this definition, 22% of women and 13% of men were considered "lean and weight stable" after five years of follow-up. All other participants were included in the comparison group. The grouping of all other participants into one comparison group, however, allows little room for in depth exploration of different groups, as does the small sample size used in this study. Importantly, comparisons with those who became overweight or obese are unable to be made, because these individuals are also grouped with those who lost weight and those who were overweight or obese for the duration of the study.

Currently there is no well-accepted definition of healthy weight maintenance. Previous definitions of weight maintenance have been developed in studies of adults and are not applicable to children because weight gain at this stage of life is a normal part of growth and development. To date, there has been no research that has used the IOTF BMI cutpoints for childhood weight status to classify healthy weight maintenance. Using this classification system has advantages over previous systems such as its simplicity, international acceptance and worldwide comparability. There is also much evidence to suggest that BMI cutpoints for adults are well linked to health outcomes such as coronary heart disease, cancer and mortality (National Institutes of Health 1998).

6.2.3 Predictors of Healthy Weight Maintenance

As mentioned previously, a recent review of childhood predictors of adult obesity concluded that a major research gap was the lack of data assessing childhood predictors of healthy weight maintenance (Parsons, Power et al. 1999). While it is well documented that childhood overweight or obesity is a significant predictor of overweight and obesity in adulthood (Parsons, Power et al. 1999), a large proportion of overweight or obese adults were healthy weight children (Serdula, Ivery et al. 1993; Venn, Thomson et al. In Press). Healthy weight children who remain healthy weight as adults might be considered those "successful" at avoiding overweight and obesity, and examination of these individuals may provide valuable insights for overweight and obesity prevention strategies and messages.

No published reports have examined predictors of healthy weight maintenance from childhood to adulthood. However, the Davison and Birch (2004) study mentioned previously examined behavioural and psychological correlates of healthy weight maintenance over five years in a sample of young adults. A small proportion of the sample (17.6%) was classified as "lean and weight stable". These were individuals whose BMI was <25kg/m^2 at baseline and whose follow-up weights remained within 5% of baseline weight. After adjustment for education, predictors of being lean and weight stable were a healthy baseline BMI, fewer weight fluctuations, lower childhood weight, better self-assessed general health and, in females, lower rates of dieting. Physical activity, smoking, alcohol consumption, depression and self-esteem were not associated with maintenance of a healthy weight.

A small number of other studies have examined predictors of weight maintenance, irrespective of baseline weight status. Ball and colleagues (Ball, Brown et al. 2002) found that a healthy weight at baseline, infrequent consumption of take-away foods, and low sitting time at follow-up were significant predictors of weight maintenance over five years in young Australian women after adjustment for occupation, marital status, student status, parity and recent motherhood. Interestingly, physical activity was not associated with weight maintenance in bivariable analyses, and smoking, low alcohol intake and current restrictive eating practices were not associated with weight maintenance in multivariable analyses. St Jeor and colleagues found that weight maintainers (those who did not gain more than 5lb over five years irrespective of baseline weight status) were more likely to have been a healthy weight at baseline, to be older and to have fewer year-to-year fluctuations (St Jeor, Brunner et al. 1997).

Crawford and colleagues found that 24.5% of participants avoided weight gain (defined as maintaining weight or losing <5% of baseline body weight) over three years in a community-based sample of 854 subjects aged 20-45 years at baseline (Crawford, Jeffery et al. 2000). Participants were involved in a weight gain prevention study, with 50% receiving education about weight control. Factors associated with weight maintenance after one year were increases in physical activity, decreases in percentage of energy intake from fat, and decreases in weekly consumption of fast food meals. Successful weight maintenance was not associated with age, education, marital status, participant type, ethnicity, BMI at 1 year follow-up, intentional weight loss or maintenance, changes in caloric intake, percentage energy intake as fat, and television viewing.

While not assessing predictors of healthy weight maintenance, Jefferey and colleagues examined prevalence and correlates of large weight gains and losses in a sample of 823 men and women aged 20-45 years involved in the Pound of Prevention study (Jeffery, McGuire et al. 2002). They found that after one year of follow-up, 76% of participants had stayed within ±5% of their initial body weight. While physical activity was not assessed in this study, predictors of large weight gain (>5% initial body weight) included regular dieting at baseline, being younger, and having lost more weight intentionally in the past, while smoking predicted large weight losses (>5% initial body weight). Baseline BMI, sex, education and dietary restraint were not significant predictors of large weight gains or losses.

6.2.4 Physical Activity & Fitness in Childhood & Weight Status in Adulthood

As mentioned previously, no published reports could be found that assessed childhood physical activity and cardiorespiratory fitness as predictors of healthy weight maintenance. However, a small number of prospective cohort studies have examined the association between childhood physical activity and/or cardiorespiratory fitness and adult overweight and obesity. These studies are predominantly European and are summarised in Tables 71 and 72. In the tables, a range of information is presented: the study authors and year of publication, the number and sex of participants, age at baseline and follow-up, the measure of physical activity or cardiorespiratory fitness used, the measure/s of adiposity, statistical analyses and adjustments, and key findings.

Table 71: The relationship between childhood physical activity & adult weight status: a summary of prospective longitudinal studies

Study/Author	N	Age (years)		Baseline PA Measure	Adiposity Measure	Analyses (Adjustments)	Key Findings
		Baseline	Follow-up				
Nth Ireland Young Hearts (Boreham, Twisk et al. 2002)	115 M & 120 F	12 & 15	22.5	Self-reported habitual PA incl. transport to/from school, PA during school beaks, after school sports participation	Σ4SF	Linear regression (social class, sexual maturity)	M: PA & sports participation at 12 & 15 years not associated with Σ4SF at 22.5 years (*β*=0.04-0.10 & 0.00-0.14); change in daily PA & sports participation between 12 & 15 years associated with adult Σ4SF (β=-0.18) F: PA & sports participation at 12 & 15 years not associated with Σ4SF at 22.5 years (*β*=0.02-0.06 & 0.01-0.05); change in daily PA & sports participation between 12 & 15 years not associated with adult Σ4SF (*β*=-0.05 to -0.11)
Danish Youth & Sports Study (Hasselstrom, Hansen et al. 2002)	88 M & 115 F	15-19	24-28	Self-reported weekly duration of sports activities in the past year	WC; %BF calculated from the Σ4SF	Linear regression (age)	M: PA in adolescence positively correlated with adult WC (*r*=0.28) & %BF (*r*=0.19) F: PA in adolescence not correlated with WC (*r*=0.05) & %BF (*r*=-0.07)
Amsterdam Growth & Health Longitudinal Study (Twisk, Kemper et al. 2002)	83 M & 98 F	13.1±0.8	27.1±0.8	Interview-administered self-reported intensity, duration & frequency of habitual PA (school, work, sports & leisure) in past 3 months	Σ4SF; WHR	Linear regression	PA not associated with Σ4SF (β=-0.01-0.09), WHR (β=-0.24-0.22); some associations with WC (β=0.03-0.13)
Leuven Longitudinal Study (Lefevre, Philippaerts et al. 2002)	176 & 166 M	13-18	35 &0	Past year sports inventory (duration & frequency)	BMI (measured height & weight); WC; WHR; Σ4SF; %BF;TREX	Pearson correlations	Adolescent PA not correlated with BMI, %BF, WC, WHR or TREX in adulthood (*r*=-0.1 to 0.09)

BMI: body mass index; WC: waist circumference; WHR: waist to hip ratio; Σ4SF: sum of four skinfolds; %BF: per cent body fat; TREX: ratio of the sum of subscapular and suprailiac skinfolds over the sum of triceps and calf skinfolds

Table 72: The relationship between childhood cardiorespiratory fitness & adult weight status: a summary of prospective longitudinal studies

Study/Author	N	Age (years)		Baseline Fitness Measure	Adiposity Measure	Analyses (Adjustments)	Key Findings
		Baseline	Follow-up				
Nth Ireland Young Hearts (Boreham, Twisk et al. 2002)	115 M & 120 F	15	22.0±1.6	Number of laps in a 20-metre shuttle run test	Σ4SF	Linear regression (social class, sexual maturity)	M: Fitness at 12 & 15 years associated with Σ4SF at 22.5 years (β=-0.37 to -0.38); change in fitness between 12 & 15 years not associated with adult Σ4SF (β=0.00) F: Fitness at 12 & 15 years not associated with Σ4SF at 22.5 years (β=-0.41 to -0.34); change in fitness between 12 & 15 years not associated with adult Σ4SF (β=-0.14)
Danish Youth & Sports Study (Hasselstrom, Hansen et al. 2002)	88 M & 115 F	15-19	24-28	$VO2_{max}$ estimated from a cycle ergometer test until exhaustion	WC; %BF calculated from the Σ4SF	Linear regression (age)	M: Fitness in adolescence not correlated with adult WC (r=0.10) & %BF (r=-0.18) F: Fitness in adolescence not correlated with WC (r=-0.08), but correlated with %BF (r=-0.27)
Amsterdam Growth & Health Longitudinal Study (Twisk, Kemper et al. 2002)	83 M & 98 F	13.1±0.8	27.1±0.8	$VO2_{max}$ estimated from a treadmill test until exhaustion	Σ4SF; WHR	Linear regression	No association between fitness & WHR; some associations with Σ4SF (β=-0.34-0.09) & WC (β=-0.23-0.34)

BMI: body mass index; WC: waist circumference; WHR: waist to hip ratio; Σ4SF: sum of four skinfolds; %BF: per cent body fat; TREX: ratio of the sum of subscapular and suprailiac skinfolds over the sum of triceps and calf skinfolds; $VO2_{max}$: maximal oxygen uptake

Of the four studies that examined the relationship between childhood physical activity and adult measures of adiposity, there was little evidence to support the existence of an association. All studies used self-reported measures of physical activity. The Northern Ireland Young Hearts project found no association between physical activity or sports participation at ages 12 or 15 years and the sum of four skinfolds at 22.5 years in either males or females (Boreham, Twisk et al. 2002). The Young Hearts study found that changes in physical activity & sports participation between the ages of 12 and 15 years were negatively associated with adult sum of four skinfolds in males, but not females. The Danish Youth and Sports Study observed an unexpected positive association between childhood physical activity and adult waist circumference and percent body fat in males, suggesting that higher levels of physical activity were associated with higher waist girths, but no association in females (Hasselstrom, Hansen et al. 2002). Similarly, the Amsterdam Growth and Health Longitudinal Study observed no association between childhood physical activity and adult skinfold thicknesses or waist to hip ratio; some associations with waist circumference were noted, but the direction differed across measures of physical activity and the sex of participants (Twisk, Kemper et al. 2002). Likewise, the Leuven Longitudinal Study saw no association between adolescent physical activity and adult measures of BMI, percent body fat, waist circumference, waist to hip ratio or ratio of the sum of subscapular and suprailiac skinfolds over the sum of triceps and calf skinfolds (TREX) (Lefevre, Philippaerts et al. 2002).

Of the three studies that assessed the relationship between childhood cardiorespiratory fitness and adult measures of adiposity, there was little evidence that an association existed. All three studies used different tests of cardiorespiratory fitness and none adjusted for adult fitness levels. In the Northern Ireland Young Hearts study, no association was noted between fitness at ages 12 or 15 years and the sum of skinfold thicknesses at age 22.5 years in females, or in changes between 12 and 15 years and adult skinfold thicknesses in males or females (Boreham, Twisk et al. 2002). However, this study did observe a significant association between fitness at age 12 and 15 years and adult skinfold thicknesses in males. The Danish Youth and Sports Study saw no association between fitness in adolescence and waist circumference in either sex or percent body fat (males only) in adulthood (Hasselstrom, Hansen et al. 2002). The Amsterdam Growth and Health Longitudinal Study saw no association between baseline fitness and adult waist to hip ratio, but saw some associations between baseline fitness and adult skinfold thicknesses and waist circumference, although these varied in strength and direction by measures and sex (Twisk, Kemper et al. 2002).

Findings from these longitudinal studies conducted in Amsterdam, Northern Ireland, Denmark and Belgium suggest that physical activity and cardiorespiratory fitness in childhood and adolescence have little influence on weight status or adiposity in adulthood. It is important to note that all these studies had methodological differences and limitations that make it difficult to draw firm conclusions from the results. For instance, these studies all had limited sample sizes, which reduces the ability to stratify by potential confounding factors such as sex and age. Additionally, none of these studies assessed children under the age of 12 years, so it is unknown whether associations differ in younger children. In addition, the Leuven Longitudinal Study only assessed boys, and the AGHLS sample size was limited to subjects from two secondary schools in Amsterdam, making generalisations of the findings difficult.

While these studies examined the effect of childhood physical activity and cardiorespiratory fitness on adult adiposity characteristics, some studies have also examined the association between patterns (change and stability) in physical activity and cardiorespiratory fitness from childhood to adulthood and adult adiposity outcomes. These are discussed in the following section.

6.2.5 Physical Activity & Fitness Patterns from Childhood to Adulthood & Adult Weight Status

A small number of prospective cohort studies have assessed the association between physical activity patterns from childhood to adulthood and adult weight status or adiposity. In most cases, patterns are assessed by examining change in physical activity or cardiorespiratory fitness category over time. It should be noted that when reference is made to changes in physical activity or cardiorespiratory fitness, such as "increased" or "decreased" over time, this refers to relative, not absolute, increases or decreases. Table 73 presents a summary of studies that have examined changes in physical activity from childhood to adulthood. In the tables, a range of information is presented: the study authors and year of publication, the number and sex of participants, age at baseline and follow-up, the measure of physical activity used, how change was defined, the measure/s of adiposity, statistical analyses and adjustments, and key findings.

Table 73: The relationship between physical activity patterns from childhood to adulthood & adult weight status: a summary of prospective longitudinal studies

Study/Author	N	Age (years)		Baseline PA Measure	Follow-Up PA Measure	PA Pattern Definition	Adiposity Measure	Analyses (Adjustments)	Key Findings
		Baseline	Follow-up						
British Birth Cohort (Parsons, Manor et al. 2006)	9,377 M & F	11, 16	23 & 45	Self-reported frequency of use of parks, recreation grounds, swimming pools & indoor play centres (reported by mother at age 11) & child report of frequency of outdoor sport	Self-reported frequency of sports participation at age 23 years & regular PA at 33 & 42 years	Top two vs bottom two PA categories at two time-points (16 & 23 years, 16 & 45 years) to create four categories: active, decreased activity, increased activity, inactive	BMI derived from measured height & weight (self-reported at age 23 years)	ANOVA	M: Those who remained inactive gained from 16-23 years had the least gains in BMI, but those who decreased their PA from 16-45 years saw the most gains in PA F: Those who remained inactive from increased their BMI more than those who remained active or who increased their PA.
Nth Finland Birth Cohort (Tammelin, Laitinen et al. 2004)	2,834 M & 2,872 F	14	31	Self-reported frequency & type of extracurricular sports participation	Self-reported frequency & duration of light & brisk PA	Four groups defined based on categories at both time-points: having become active, having become inactive, persistently active, persistently inactive	BMI derived from measured height & weight; measured WC	Multinomial regression (occupational PA, education, alcohol, smoking, BMI at age 14, in females parity)	M: Becoming inactive, but not persistent inactivity, associated with ↑ odds of overweight & obesity; persistent inactivity associated with ↑ odds of mild & severe abdominal obesity F: Becoming inactive & persistent inactivity associated with ↑ odds of obesity; becoming inactive, but not persistent inactivity, associated with ↑ odds of severe abdominal obesity

Study/Author	N	Age (years)		Baseline PA Measure	Follow-Up PA Measure	PA Pattern Definition	Adiposity Measure	Analyses (Adjustments)	Key Findings
		Baseline	Follow-up						
Young Finns (Yang, Telama et al. 2006)	626 M & 693 F	9-18	30-39	Self-reported frequency & intensity of LTPA, & frequency of sports club competitions & training	Self-reported intensity of PA, frequency & duration of vigorous PA, participation in organised PA	Three categories created at baseline & follow-up from tertile splits. Participants then defined as increasingly active, decreasingly active, persistently active, persistently inactive	BMI (measured height & weight); WC	Multinomial logistic regression (age, BMI in youth, sum of skinfolds in youth, place of residence, education, occupation, marital status, no. of children, smoking)	M: No association between PA patterns & adult overweight or obesity (using BMI or WC) F: Decreasing PA was associated with overweight & obesity (using BMI or WC), while persistent inactivity was associated with overweight only (using BMI)
Danish Youth & Sports Study (Hasselstrom, Hansen et al. 2002)	88 M & 115 F	15-19	24-28	Self-reported weekly duration of sports activities in the past year	Self-reported weekly duration of sports activities in the past year	Patterns assessed as change in absolute values	WC; %BF calculated from the Σ4SF	Partial correlation coefficients (age)	M: PA correlated with WC & %BF (r=-0.31 & -0.23) F: No significant correlation observed (r=0.05 & 0.02 for WC & %BF)

BMI: body mass index; WC: waist circumference; WHR: waist to hip ratio; Σ4SF: sum of four skinfolds; %BF: per cent body fat; TREX: ratio of the sum of subscapular and suprailiac skinfolds over the sum of triceps and calf skinfolds

Four prospective cohort studies have examined physical activity patterns from childhood to adulthood and weight status or adiposity outcomes in adult. All studies used self-reported measures of physical activity. Many of the studies saw that decreases in physical activity or persistent physical inactivity were associated with increased adiposity measures or risk of overweight and obesity. Although there were some inconsistencies, these are likely due to the different measures of physical activity and adiposity and different methods used to define patterns. For instance, females in the British Birth Cohort who remained inactive had increases in BMI greater than those who remained active or increased their physical activity. Males who remained inactive from 16-23 years had the least gains in BMI while those who decreased their PA from 16-45 years saw the most gains in BMI (Parsons, Manor et al. 2006). Becoming inactive (but not persistent inactivity) was associated with increased odds of overweight and obesity in males in the Northern Finland Birth Cohort, although persistent inactivity (but not becoming inactive) was associated with increased odds of mild and severe abdominal obesity (Tammelin, Laitinen et al. 2004). In females, becoming inactive and persistent inactivity were both associated with increased odds of obesity, while becoming inactive (but not persistent inactivity) was associated with increased odds of severe abdominal obesity.

The Young Finns study observed no association between physical activity patterns and adult overweight or obesity (defined using either BMI or waist circumference) in males, but females who decreased their physical activity were more likely to be overweight or obese (defined using either BMI or waist circumference) and persistent inactivity was associated with overweight (but not obesity) (Yang, Telama et al. 2006). In contrast, the Danish Youth and Sports Study saw no associations in females but saw that absolute physical activity patterns were correlated with waist circumference and percent body fat in males (Hasselstrom, Hansen et al. 2002).

The Danish Youth and Sports Study was the only study that examined cardiorespiratory fitness patterns from childhood to adulthood and the association with adult weight status. This study of 88 males and 115 females aged 15-19 years at baseline and followed to the age of 24-28 years estimated maximal oxygen uptake from a cycle ergometer test until exhaustion (Hasselstrom, Hansen et al. 2002). Cardiorespiratory fitness patterns were assessed as change in absolute values between baseline and follow-up. In this study, changes in fitness were associated with adult waist girth in males (r=-0.45, p<0.01) and per cent body fat in both males (r=-0.22, p<0.1) and females (r=-0.22, p<0.05).

These findings provide some evidence of an association between physical activity and cardiorespiratory fitness patterns from childhood to adulthood and weight status or adiposity in adulthood. Each of these studies used different measures of physical activity and cardiorespiratory fitness and therefore different definitions of patterns. Baseline age differed amongst studies, as did the length of follow-up and analysis techniques. These disparities are likely responsible for differences in findings. None of these studies used the recently developed internationally-accepted IOTF age- and sex-specific cutpoints for children to define healthy weight, overweight and obesity (Cole, Bellizzi et al. 2000), which may be useful for making international comparisons.

6.3 Aims & Research Questions

The aim of this chapter was to examine the longitudinal relationships between childhood physical activity and cardiorespiratory fitness, adult weight status and healthy weight maintenance. The specific research questions were:

1. Does childhood physical activity predict healthy weight maintenance from childhood to adulthood?
2. Does childhood cardiorespiratory fitness predict healthy weight maintenance from childhood to adulthood?
3. Do physical activity patterns (changes or stability) predict healthy weight maintenance from childhood to adulthood?
4. Do cardiorespiratory fitness patterns (changes or stability) predict healthy weight maintenance from childhood to adulthood?

6.4 Methods

6.4.1 Participants

The subjects for this study were participants in the ASHFS 1985 who also took part in the CDAH follow-up study. The sample is described in detail in Chapter 2. Briefly, 8,498 children aged 7-15 years were randomly selected from 109 government, Catholic and independent schools from all states and territories in Australia. Schools were selected with a probability proportional to size and children were then selected using simple random sampling. In 2004-6, 2,053 young adults aged 26-36 years participated in the CDAH follow-up study (32% of those successfully traced and residing in states where data collection had taken place up until December 2005). Participants in this study were eligible for inclusion if the following were available:

- Measured height and weight data from the ASHFS 1985 and the CDAH follow-up study
- Self-reported physical activity data or cardiorespiratory fitness data from the ASHFS 1985
- Self-reported physical activity data from the CDAH follow-up study

Table 74 presents the number of participants with data available for analysis in this chapter.

Table 74: Number of participants & type of data available for adiposity, physical activity & cardiorespiratory fitness at baseline & follow-up in the CDAH follow-up study

Type of Measure	Baseline Measure	Follow-Up Measure	Males	Females
Measures of Adiposity	BMI	BMI	982	997
	Waist Circumference	Waist Circumference	982	997
Physical Activity	Self-Report	Self-Report	1,036	1,180
Cardiorespiratory Fitness	PWC_{170}	PWC_{170}	275	266

6.4.2 Measures

The measures used in this study are described in detail in Chapter 2. Briefly, 6,559 children aged 9-15 years completed a questionnaire that asked about the frequency, duration and intensity of physical activity (school sport, school physical education, active commuting and other activities) in the past week; the number of extracurricular sports participated in during the past year; and the intensity of usual physical activity at recess and lunchtime at school. As an estimate of cardiorespiratory fitness, those aged 9, 12 and 15 years completed a PWC_{170} cycle ergometer test (n=2,595). All children had their height and weight measured.

At follow-up, participants completed the long version of the International Physical Activity Questionnaire (IPAQ-L). While information on daily steps was collected using pedometers, these data were not included in these analyses because of a lack of comparable baseline data. Height was measured to the nearest 0.1cm using a Leicester stadiometer; and weight was measured to the nearest 0.1kg using Schoenle digital scales. Participants completed a PWC_{170} cycle ergometer test, which involved administering increasing workloads over three, four-minute periods to raise heart rate within predetermined ranges. Sociodemographic information (employment status, occupation, education level, marital status, smoking, and parity in females) was also collected via a general self-completed questionnaire.

6.4.3 Statistical Methods

Definitions

The treatment of baseline and follow-up adiposity, physical activity and cardiorespiratory fitness variables has been described in the previous three chapters. Refer to these chapters (3, 4 and 5) for further detail. The main outcome, "healthy weight maintenance" was defined as those participants who were healthy weight at baseline (defined using internationally-accepted age- and sex-specific cutpoints detailed in Chapter 2) and healthy weight at follow-up (BMI<25kg/m^2). "Gainers" were those healthy weight children who became overweight (BMI≥25kg/m^2).

Physical activity and cardiorespiratory fitness patterns were determined using two methods. The first method (Method 1)was similar to the method employed in the Young Finns study (Yang, Telama et al. 2006) and provides information on the direction of the physical activity or cardiorespiratory fitness pattern. Physical activity and cardiorespiratory fitness at both time points was categorised into three groups based on tertile splits. The first third was deemed "low", the second "moderate" and the third "high". Participants in the low group at both time points were deemed "persistently inactive/unfit"; those in the moderate group or high group at both time points were deemed "persistently active/fit"; those who moved from the high or moderate group to the moderate or low group were deemed "decreasingly active/fit"; and those who moved from the low or moderate group to the moderate or high group were deemed "increasingly active/fit" (Table 75).

Table 75: Physical activity & cardiorespiratory fitness patterns from childhood to adulthood in the CDAH follow-up study: Method 1

		Adulthood		
		Low	**Moderate**	**High**
Childhood	**Low**	Persistently Inactive/Unfit	Increasing	Increasing
	Moderate	Decreasing	Persistently Active/Fit	Increasing
	High	Decreasing	Decreasing	Persistently Active/Fit

The second method for assessing changes in physical activity and cardiorespiratory fitness patterns over time was to use standardised scores (z-scores) from childhood to adulthood to examine the magnitude of changes (Method 2). Physical activity variables were log-transformed to impose normality prior to converting values to z-scores. Within strata of sex and age, z-scores were calculated as the difference between individual values and mean values divided by the standard deviation. Childhood z-scores were then subtracted from adult z-scores to generate change scores, and participants were then grouped into categories of change from childhood to adulthood (Table 76). Due to the smaller number of participants who completed a PWC_{170} cycle ergometer test at baseline and follow-up, the two "decrease" and the two "increase" categories were collapsed to form one "decrease" (<-0.5) and one "increase" (>0.5) category, to form three categories for these analyses.

Table 76: Physical activity & cardiorespiratory fitness patterns from childhood to adulthood in the CDAH follow-up study: Method 2

Change in z-score	PA Pattern Category	Fitness Pattern Category
Less than -1.0	Large decrease	Decrease
-1.0 to -0.5	Moderate decrease	Decrease
-0.5 to 0.5	Stable	Stable
0.5 to 1.0	Moderate increase	Increase
Greater than 1.0	Large increase	Increase

Analyses

A log binomial regression model was used to determine whether childhood sociodemographic factors were associated with healthy weight maintenance. This model was adjusted for adult sociodemographic factors to determine the independent effect of childhood factors on adult healthy weight status. Log binomial regression was also used to determine whether adult sociodemographic factors were associated with being a healthy weight maintainer adjusted for baseline age, with and without adjustment for childhood sociodemographic factors. Relative risks and 95% confidence intervals are presented for males and females separately. The sociodemographic factors that demonstrated significant associations with healthy weight maintenance were treated as potential confounders in the multivariable analyses.

Log binomial regression was used to determine whether childhood physical activity was associated with maintaining a healthy weight from childhood to adulthood. Sociodemographic factors that were significant in the models above were included in analyses, as was age. Relative risks and 95% confidence intervals are presented for males and females separately, stratified by school level. The same analyses were conducted to determine whether childhood cardiorespiratory fitness was associated with maintaining a healthy weight from childhood to adulthood.

The association between physical activity and cardiorespiratory fitness patterns from childhood to adulthood and healthy weight maintenance was investigated using a log binomial regression model. Sociodemographic factors that were significantly associated with healthy weight maintenance were included as covariates in the models. Relative risks and 95% confidence intervals are presented for males and females separately, stratified by school level.

6.5 Results

This section first presents findings from investigations of the association between sociodemographic factors and healthy weight maintenance to establish potential confounders to be included in the multivariable analyses. The relationship between childhood physical activity and cardiorespiratory fitness and the likelihood of being a healthy weight maintainer is then explored. Finally, the relationship between healthy weight maintenance and physical activity and cardiorespiratory fitness patterns from childhood to adulthood is examined.

6.5.1 Are Sociodemographic Factors Associated with Healthy Weight Maintenance?

Childhood sociodemographic factors had little influence on the likelihood of maintaining a healthy weight in adulthood and in most cases the influence was attenuated after adjustment for adult sociodemographic factors (Table 77 and 78). School type in both males and females was associated with an increased likelihood of maintaining a healthy weight from childhood to adulthood, but not at statistically significant levels, while area-level SES showed no association. Males born outside Australia had an increased likelihood of maintaining a healthy weight from childhood to adulthood, but not females. Mother's education level (retrospectively recalled) was bivariably associated with healthy weight maintenance in males and father's education level (retrospectively recalled) was bivariably associated with healthy weight maintenance in females. These associations ceased to be significant after adjusting for adult sociodemographic factors.

Table 77: Relative risk (RR) of maintaining a healthy weight from childhood to adulthood based on childhood sociodemographic factors in males in the CDAH follow-up study

Childhood Factor	% HWM	(n/N)	RR[a]	(95% CI)	RR[b]	(95% CI)
Area-level SES[c]						
Quartile 1	44.0	(81/184)	1.0	(ref)	1.0	(ref)
Quartile 2	44.5	(85/189)	0.89	(0.61-1.30)	0.84	(0.64-1.10)
Quartile 3	31.9	(83/260)	1.27	(0.88-1.84)	1.21	(0.93-1.58)
Quartile 4	33.3	(21/63)	1.18	(0.81-1.72)	1.09	(0.85-1.39)
School Type						
Government	40.2	(250/622)	1.0	(ref)	1.0	(ref)
Catholic	42.7	(79/185)	1.05	(0.87-1.26)	1.14	(0.94-1.39)
Independent	44.2	(34/77)	1.06	(0.81-1.39)	1.14	(0.90-1.44)
Smoking						
Never smoked	43.4	(175/403)	1.0	(ref)	1.0	(ref)
A few puffs	34.2	(63/184)	0.84	(0.66-1.06)	0.82	(0.62-1.09)
<10 cigarettes	32.0	(16/50)	0.84	(0.55-1.30)	1.09	(0.69-1.73)
>10 cigarettes	29.0	(22/76)	0.78	(0.53-1.17)	0.77	(0.45-1.29)
Parental Smoking						
Neither smoke	39.9	(174/436)	1.0	(ref)	1.0	(ref)
Both smoke	35.7	(30/84)	0.90	(0.67-1.23)	0.92	(0.64-1.31)
Mother smokes	34.0	(18/53)	0.88	(0.60-1.30)	1.01	(0.67-1.52)
Father smokes	37.9	(53/140)	0.95	(0.75-1.21)	0.99	(0.76-1.29)
Parental PA						
Both parents active	41.1	(51/124)	1.0	(ref)	1.0	(ref)
Mother only active	36.0	(40/111)	0.88	(0.64-1.22)	1.04	(0.77-1.40)
Father only active	43.9	(65/148)	1.06	(0.80-1.39)	1.00	(0.77-1.29)
Both parents inactive	38.1	(107/281)	0.95	(0.73-1.22)	1.03	(0.80-1.33)
Country of Birth						
Australia	37.6	(248/659)	1.0	(ref)	1.0	(ref)
Outside Australia	50.9	(27/53)	**1.34**	**(1.02-1.76)**	**1.60**	**(1.25-2.06)**
Language at Home						
English	38.5	(242/628)	1.0	(ref)	1.0	(ref)
Non-English	40.0	(34/85)	1.13	(0.87-1.48)	1.06	(0.77-1.47)
Mother's Education[d]						
University	47.8	(75/157)	1.0	(ref)	1.0	(ref)
Vocational/Diploma	46.5	(59/127)	1.00	(0.79-1.28)	1.21	(0.92-1.58)
School Only[e]	36.6	(178/486)	**0.81**	**(0.66-0.99)**	0.95	(0.75-1.19)
Father's Education[d]						
University	48.7	(93/191)	1.0	(ref)	1.0	(ref)
Vocational/Diploma	39.4	(95/241)	0.82	(0.66-1.01)	0.94	(0.75-1.18)
School Only[e]	38.7	(125/323)	0.82	(0.67-1.00)	0.83	(0.66-1.04)
Mother's Occupation[d]						
Managers/Professionals	44.4	(88/198)	1.0	(ref)	1.0	(ref)
White Collar	38.3	(93/243)	0.87	(0.70-1.08)	0.91	(0.71-1.16)
Blue Collar	39.1	(43/110)	0.95	(0.72-1.25)	1.04	(0.77-1.42)
Not in Labour Force	40.6	(97/239)	0.95	(0.77-1.17)	1.00	(0.79-1.27)
Father's Occupation[d f]						
Managers/Professionals	44.6	(204/457)	1.0	(ref)	1.0	(ref)
White Collar	35.6	(16/45)	0.85	(0.56-1.28)	0.86	(0.54-1.35)
Blue Collar	37.4	(110/294)	0.88	(0.74-1.05)	0.97	(0.79-1.19)

HWM: Healthy weight maintainers
[a] Relative risk adjusted for age at baseline

[b] Relative risk adjusted for age at baseline & adult sociodemographic factors (occupation, highest level of education, marital status, smoking & number of children in females only)
[c] Based on the socioeconomic index for areas, described in detail in Chapter 2, with Quartile 1 being the most disadvantaged and Quartile 4 being the least disadvantaged
[d] Reported retrospectively
[e] School only includes 2 participants who reported that their mother did not complete school & 9 participants who reported that their father did not complete school
[f] Father not in the labour force excluded from this analysis due to small cell size

Table 78: Relative risk (RR) of maintaining a healthy weight from childhood to adulthood based on childhood sociodemographic factors in females in the CDAH follow-up study

Childhood Factor	% HWM	(n/N)	RR[a]	(95% CI)	RR[b]	(95% CI)
Area-level SES[c]						
Quartile 1	63.6	(112/176)	1.0	(ref)	1.0	(ref)
Quartile 2	69.2	(135/195)	0.89	(0.72-1.10)	0.94	(0.79-1.11)
Quartile 3	62.1	(159/256)	0.99	(0.80-1.23)	1.02	(0.85-1.22)
Quartile 4	68.1	(32/47)	0.91	(0.73-1.14)	0.94	(0.79-1.12)
School Type						
Government	64.0	(415/648)	1.0	(ref)	1.0	(ref)
Catholic	69.0	(127/184)	1.08	(0.97-1.21)	1.13	(1.00-1.27)
Independent	71.1	(32/45)	1.08	(0.88-1.32)	1.16	(0.92-1.46)
Smoking						
Never smoked	67.8	(271/400)	1.0	(ref)	1.0	(ref)
A few puffs	62.3	(91/146)	0.93	(0.80-1.08)	0.93	(0.78-1.11)
<10 cigarettes	54.0	(27/50)	0.82	(0.62-1.07)	0.89	(0.66-1.21)
>10 cigarettes	62.8	(54/86)	0.95	(0.78-1.16)	0.87	(0.65-1.16)
Parental Smoking						
Neither smoke	65.7	(253/385)	1.0	(ref)	1.0	(ref)
Both smoke	56.3	(54/96)	0.86	(0.71-1.05)	0.90	(0.71-1.15)
Mother smokes	61.3	(46/75)	0.93	(0.77-1.13)	0.93	(0.74-1.19)
Father smokes	70.5	(86/122)	1.08	(0.94-1.23)	1.08	(0.94-1.26)
Parental PA						
Both parents active	64.5	(89/138)	1.0	(ref)	1.0	(ref)
Mother only active	65.0	(78/120)	1.01	(0.84-1.21)	0.97	(0.80-1.18)
Father only active	68.0	(83/122)	1.05	(0.88-1.25)	1.14	(0.95-1.37)
Both parents inactive	63.5	(167/263)	0.99	(0.85-1.16)	1.04	(0.87-1.25)
Country of Birth						
Australia	64.7	(418/646)	1.0	(ref)	1.0	(ref)
Outside Australia	66.7	(24/36)	1.04	(0.82-1.31)	1.09	(0.84-1.40)
Language at Home						
English	64.5	(401/622)	1.0	(ref)	1.0	(ref)
Non-English	68.9	(42/61)	1.08	(0.91-1.29)	1.14	(0.97-1.33)
Mother's Education[d]						
University	72.6	(90/124)	1.0	(ref)	1.0	(ref)
Vocational/Diploma	65.5	(114/174)	0.91	(0.79-1.06)	0.90	(0.76-1.07)
School Only[e]	63.2	(321/508)	0.89	(0.78-1.01)	0.88	(0.77-1.01)
Father's Education[d]						
University	73.2	(134/183)	1.0	(ref)	1.0	(ref)
Vocational/Diploma	61.5	(150/244)	**0.86**	**(0.75-0.98)**	0.85	(0.72-1.00)
School Only[e]	63.2	(223/353)	**0.88**	**(0.78-0.99)**	0.88	(0.76-1.02)
Mother's Occupation[d]						
Managers/Professionals	69.3	(142/205)	1.0	(ref)	1.0	(ref)
White Collar	63.9	(170/266)	0.93	(0.82-1.06)	0.94	(0.81-1.08)

Childhood Factor	% HWM	(n/N)	RR[a]	(95% CI)	RR[b]	(95% CI)
Blue Collar	60.7	(71/117)	0.90	(0.75-1.06)	0.86	(0.71-1.05)
Not in Labour Force	67.0	(158/236)	0.98	(0.86-1.12)	1.00	(0.88-1.13)
Father's Occupation[d f]						
Managers/Professionals	67.0	(288/430)	1.0	(ref)	1.0	(ref)
White Collar	62.5	(25/40)	0.93	(0.72-1.20)	0.92	(0.70-1.20)
Blue Collar	64.2	(217/338)	0.97	(0.88-1.08)	0.96	(0.84-1.08)

HWM: healthy weight maintainers
[a] Relative risk adjusted for age at baseline
[b] Relative risk adjusted for age at baseline & adult sociodemographic factors (occupation, highest level of education, marital status, smoking & number of children in females only)
[c] Based on the socioeconomic index for areas, described in detail in Chapter 2, with Quartile 1 being the most disadvantaged and Quartile 4 being the least disadvantaged
[d] Reported retrospectively
[e] School only includes 3 participants who reported that their mother did not complete school & 7 participants who reported that their father did not complete school
[f] Father not in the labour force excluded from this analysis due to small cell size

Highest level of education level was associated with healthy weight maintenance in males and females, as was being in a de facto relationship (Table 79 and 80). Males who smoked daily were more likely to be healthy weight maintainers than non-smokers, while women with three or more children were less likely to be healthy weight maintainers than those with no children; this association became non-significant after adjusting for age and childhood sociodemographic factors.

Table 79: Relative risk (RR) of maintaining a healthy weight from childhood to adulthood based on adult sociodemographic factors in males in the CDAH follow-up study

Adulthood Factor	% HWM	(n/N)	RR[a]	(95% CI)	RR[b]	(95% CI)
Occupation Level						
Manager/professional	38.6	(151/391)	1.0	(ref)	1.0	(ref)
White collar	50.0	(22/44)	1.25	(0.92-1.71)	1.40	(0.99-1.97)
Blue collar	34.1	(73/214)	0.85	(0.69-1.06)	0.88	(0.69-1.12)
Not in labour force[c]	59.1	(13/22)	-	-	-	-
Education						
University/higher degree	46.2	(121/262)	1.0	(ref)	1.0	(ref)
Diploma/vocational	30.8	(76/247)	**0.68**	**(0.54-0.86)**	**0.72**	**(0.56-0.92)**
School only	37.6	(62/165)	0.84	(0.67-1.07)	0.90	(0.69-1.16)
Marital Status						
Single	48.4	(90/186)	1.0	(ref)	1.0	(ref)
De Facto	39.0	(39/100)	**0.72**	**(0.59-0.89)**	**0.66**	**(0.54-0.83)**
Married	33.5	(129/385)	0.81	(0.61-1.09)	0.81	(0.60-1.10)
Separated/Divorced	45.5	(5/11)	0.98	(0.49-1.94)	0.99	(0.60-1.98)
Smoking						
Non-Smoker	36.8	(191/519)	1.0	(ref)	1.0	(ref)
Occasional Smoker	40.4	(21/52)	1.12	(0.80-1.56)	1.11	(0.78-1.58)
Daily Smoker	46.0	(51/111)	**1.29**	**(1.03-1.62)**	**1.36**	**(1.06-1.73)**

HWM: Healthy weight maintainers
[a] Relative risk adjusted for age at baseline
[b] Relative risk adjusted for age at baseline & child sociodemographic factors (country of birth & mother's education)
[c] Those males not in the labour force excluded from analysis due to small cell size

Table 80: Relative risk (RR) of maintaining a healthy weight from childhood to adulthood based on adult sociodemographic factors in females in the CDAH follow-up study

Adulthood Factor	% HWM	(n/N)	RR[a]	(95% CI)	RR[b]	(95% CI)
Occupation Level						
Manager/professional	67.2	(231/344)	1.0	(ref)	1.0	(ref)
White collar	64.2	(120/187)	0.97	(0.85-1.11)	1.00	(0.85-1.17)
Blue collar	64.7	(22/34)	0.97	(0.75-1.26)	1.07	(0.83-1.39)
Not in labour force	55.1	(59/107)	0.82	(0.68-0.99)	0.89	(0.74-1.08)
Education						
University/higher degree	71.8	(222/309)	1.0	(ref)	1.0	(ref)
Diploma/vocational	56.7	(93/164)	0.79	(0.68-0.92)	**0.80**	**(0.68-0.94)**
School only	59.1	(117/198)	0.83	(0.73-0.95)	**0.88**	**(0.70-1.01)**
Marital Status[c]						
Single	63.1	(94/149)	1.0	(ref)	1.0	(ref)
De Facto	69.8	(67/96)	1.10	(0.92-1.33)	1.08	(0.93-1.26)
Married	63.8	(257/403)	1.03	(0.89-1.19)	1.10	(0.91-1.33)
Separated/Divorced	61.5	(16/26)	0.99	(0.71-1.38)	1.11	(0.80-1.53)
Smoking						
Non-Smoker	63.8	(337/528)	1.0	(ref)	1.0	(ref)
Occasional Smoker	67.4	(33/49)	1.05	(0.86-1.29)	1.06	(0.87-1.30)
Daily Smoker	66.3	(63/95)	1.03	(0.88-1.21)	1.02	(0.86-1.21)
Parity						
0 children	67.9	(195/287)	1.0	(ref)	1.0	(ref)
1 child	65.8	(75/114)	0.98	(0.83-1.14)	0.96	(0.82-1.13)
2 children	63.5	(120/189)	0.95	(0.83-1.10)	1.00	(0.86-1.16)
3+ children	52.4	(44/84)	**0.79**	**(0.63-0.98)**	0.85	(0.68-1.07)

HWM: Healthy weight maintainers
[a] Relative risk adjusted for age at baseline
[b] Relative risk adjusted for age at baseline & child sociodemographic factors (father's education)
[c] One (1) widowed female excluded from analysis

6.5.2 Are Healthy Weight, Active Children More Likely to be Healthy Weight Maintainers?

Overall, childhood physical activity had little influence on the likelihood of maintaining a healthy weight from childhood to adulthood, independently of adult physical activity. This finding was observed for extracurricular sport (Appendix 16, Table 37), school sport (Appendix 16, Tables 38 and 39), active commuting (Appendix 16, Tables 40 and 41), non-organised physical activity (Appendix 16, Tables 42 and 43) and total physical activity (Appendix 16, Table 44). However, there were a small number of exceptions. In males who were primary school-aged at baseline, greater frequency and duration of school physical education was associated with an increased likelihood of being a healthy weight maintainer, independently of adult physical activity and sociodemographic factors (Tables 81 and 82).

Table 81: Relative risk (RR) of being a healthy weight adult (versus being an overweight adult) according to frequency of participation in childhood school physical education

Sex, School Level & Frequency of PE	% HWM	(n/N)	RR	(95% CI)	Adj. RR[a]	(95% CI)	Adj. RR[b]	(95% CI)
Males								
Primary School								
Never	35.9	(47/131)	1.0	(ref)	1.0	(ref)	1.0	
1/week	49.6	(61/123)	**1.38**	**(1.03-1.85)**	**1.43**	**(1.06-1.94)**	**1.53**	**(1.04-2.23)**
2/week	48.4	(31/64)	1.35	(0.96-1.90)	1.37	(0.96-1.97)	1.38	(0.91-2.09)
3+/week	52.0	(26/50)	**1.45**	**(1.02-2.06)**	**1.62**	**(1.14-2.32)**	**1.99**	**(1.32-3.01)**
				P_{trend} = 0.30		P_{trend} = 0.14		P_{trend} <0.05
Secondary School								
Never	28.7	(27/94)	1.0	(ref)	1.0	(ref)	1.0	(ref)
1/week	33.7	(28/83)	1.17	(0.76-1.82)	1.16	(0.74-1.82)	0.85	(0.52-1.40)
2/week	34.2	(42/123)	1.19	(0.80-1.78)	1.20	(0.79-1.82)	0.90	(0.57-1.42)
3+/week	32.3	(21/65)	1.13	(0.70-1.81)	1.13	(0.70-1.82)	0.99	(0.59-1.64)
				P_{trend} = 0.55		P_{trend} = 0.55		P_{trend} = 0.74
Females								
Primary School								
Never	66.4	(69/104)	1.0	(ref)	1.0	(ref)	1.0	(ref)
1/week	66.9	(81/121)	1.01	(0.84-1.21)	1.03	(0.85-1.25)	0.96	(0.81-1.15)
2/week	66.2	(43/65)	1.00	(0.80-1.24)	1.02	(0.80-1.29)	0.97	(0.80-1.18)
3+/week	63.9	(39/61)	0.96	(0.76-1.22)	1.02	(0.81-1.29)	0.95	(0.77-1.17)
				P_{trend} = 0.52		P_{trend} = 0.94		P_{trend} = 0.55
Secondary School								
Never	67.4	(30/62)	1.0	(ref)	1.0	(ref)	1.0	
1/week	54.6	(36/66)	0.81	(0.62-1.05)	0.81	(0.63-1.05)	0.83	(0.62-1.12)
2/week	66.9	(85/127)	0.99	(0.82-1.20)	0.98	(0.81-1.19)	1.00	(0.80-1.25)
3+/week	56.7	(34/60)	0.84	(0.65-1.09)	0.86	(0.66-1.12)	0.86	(0.63-1.17)
				P_{trend} = 0.50		P_{trend} = 0.39		P_{trend} = 0.37

HWM: Healthy weight maintainers; PE: physical education

[a] Relative risk adjusted for adult physical activity

[b] Relative risk adjusted for adult physical activity plus country of birth, mother's education, highest level of education, marital status & smoking status in males; father's education, highest level of education, marital status & number of children in females

Table 82: Relative risk (RR) of being a healthy weight adult (versus being an overweight adult) according to duration of childhood school physical education

Sex, School Level & Duration of School PE	**% HWM**	**(n/N)**	**RR**	**(95% CI)**	**Adj. RR[a]**	**(95% CI)**	**Adj. RR[b]**	**(95% CI)**
Males								
Primary School								
<30m/wk	35.8	(53/148)	1.0	(ref)	1.0	(ref)	1.0	(ref)
30-59m/wk	49.5	(49/99)	**1.38**	**(1.03-1.85)**	**1.49**	**(1.09-2.03)**	**1.70**	**(1.16-2.51)**
60-89m/wk	54.8	(40/73)	**1.53**	**(1.14-2.07)**	**1.69**	**(1.23-2.31)**	**1.64**	**(1.12-2.41)**
90+m/wk	47.9	(23/48)	1.34	(0.93-1.93)	1.43	(0.98-2.10)	**1.58**	**(1.16-2.51)**
				P_{trend} = 0.21		P_{trend} = 0.09		P_{trend} <0.05
Secondary School								
<30m/wk	28.4	(27/95)	1.0	(ref)	1.0	(ref)	1.0	(ref)
30-59m/wk	37.8	(14/37)	1.33	(0.79-2.24)	1.21	(0.69-2.15)	0.94	(0.50-1.77)
60-89m/wk	27.9	(19/68)	0.98	(0.60-1.62)	1.05	(0.64-1.73)	0.78	(0.44-1.37)
90+m/wk	35.2	(58/165)	1.24	(0.85-1.81)	1.23	(0.84-1.81)	0.97	(0.63-1.49)
				P_{trend} = 0.37		P_{trend} = 0.32		P_{trend} = 0.59
Females								
Primary School								
<30m/wk	67.5	(85/126)	1.0	(ref)	1.0	(ref)	1.0	(ref)
30-59m/wk	68.6	(70/102)	1.02	(0.85-1.22)	1.06	(0.88-1.27)	0.94	(0.77-1.14)
60-89m/wk	60.6	(43/71)	0.90	(0.72-1.12)	0.90	(0.73-1.12)	0.90	(0.73-1.12)
90+m/wk	65.4	(34/52)	0.97	(0.77-1.22)	1.02	(0.81-1.29)	0.94	(0.76-1.16)
				P_{trend} = 0.35		P_{trend} = 0.70		P_{trend} = 0.39
Secondary School								
<30m/wk	67.4	(62/92)	1.0	(ref)	1.0	(ref)	1.0	(ref)
30-59m/wk	46.4	(13/28)	0.69	(0.45-1.05)	0.70	(0.45-1.07)	0.69	(0.43-1.09)
60-89m/wk	61.1	(44/72)	0.91	(0.72-1.14)	0.90	(0.71-1.14)	0.89	(0.70-1.15)
90+m/wk	64.1	(98/153)	0.95	(0.79-1.14)	0.95	(0.79-1.14)	0.95	(0.80-1.13)
				P_{trend} = 0.87		P_{trend} = 0.68		P_{trend} = 0.74

HWM: Healthy weight maintainers; PE: physical education
[a] Relative risk adjusted for adult physical activity
[b] Relative risk adjusted for adult physical activity plus country of birth, mother's education, highest level of education, marital status & smoking status in males; father's education, highest level of education, marital status & number of children in females

Unexpectedly, males who were in secondary school at baseline were less likely to be healthy weight maintainers if they participated in higher intensity recess and lunch time physical activity (Table 83). This association remained significant after adjusting for adult physical activity and sociodemographic factors.

Table 83: Relative risk (RR) of being a healthy weight adult (versus being an overweight adult) according to intensity of school recess & lunchtime physical activity in childhood

Sex, School Level & Intensity of Recess & Lunch PA	% HWM	(n/N)	RR	(95% CI)	Adj. RR[a]	(95% CI)	Adj. RR[b]	(95% CI)
Males								
Primary School								
Low	33.3	(3/9)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Low-Mod	41.2	(14/34)	1.24	(0.45-3.38)	1.03	(0.38-2.76)	0.93	(0.33-2.66)
Mod-High	34.1	(31/91)	1.02	(0.39-2.69)	0.83	(0.32-2.13)	0.72	(0.27-1.94)
High	50.0	(112/224)	1.50	(0.59-3.81)	1.24	(0.50-2.08)	1.19	(0.46-3.06)
				P_{trend} <0.05		P_{trend} = 0.07		P_{trend} = 0.10
Secondary School								
Low	46.9	(30/64)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Low-Mod	27.9	(22/79)	**0.59**	**(0.38-0.92)**	0.64	(0.41-1.00)	**0.61**	**(0.39-0.96)**
Mod-High	19.7	(12/61)	**0.42**	**(0.24-0.74)**	**0.45**	**(0.25-0.79)**	**0.39**	**(0.19-0.81)**
High	34.2	(51/149)	0.73	(0.52-1.03)	0.76	(0.53-1.08)	0.83	(0.58-1.18)
				P_{trend} = 0.24		P_{trend} = 0.31		P_{trend} = 0.62
Females								
Primary School								
Low	60.0	(9/15)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Low-Mod	73.9	(34/46)	1.23	(0.79-1.93)	1.24	(0.79-1.94)	1.08	(0.69-1.68)
Mod-High	64.0	(73/114)	1.07	(0.69-1.65)	1.08	(0.70-1.67)	0.93	(0.62-1.41)
High	67.1	(114/170)	1.12	(0.73-1.71)	1.13	(0.73-1.72)	0.95	(0.63-1.43)
				P_{trend} = 0.93		P_{trend} = 0.99		P_{trend} = 0.77
Secondary School								
Low	68.6	(70/102)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Low-Mod	61.5	(102/166)	0.90	(0.75-1.07)	0.90	(0.75-1.07)	0.90	(0.76-1.07)
Mod-High	57.1	(24/42)	0.83	(0.62-1.12)	0.87	(0.64-1.18)	0.79	(0.56-1.13)
High	61.5	(16/26)	0.90	(0.64-1.25)	0.92	(0.66-1.28)	0.84	(0.60-1.17)
				P_{trend} = 0.24		P_{trend} = 0.30		P_{trend} = 0.32

HWM: Healthy weight maintainers; PA: physical activity
[a] Relative risk adjusted for adult physical activity
[b] Relative risk adjusted for adult physical activity plus country of birth, mother's education, highest level of education, marital status & smoking status in males; father's education, highest level of education, marital status & number of children in females

6.5.3 Are Healthy Weight, Fit Children More Likely to be Healthy Weight Maintainers?

Unexpectedly, cardiorespiratory fitness was inversely associated with being a healthy weight maintainer in those at primary school at baseline, but was positively associated with being a healthy weight maintainer in secondary school-aged females, independent of adult cardiorespiratory fitness (Table 84).

Table 84: Relative risk (RR) of maintaining a healthy weight (versus becoming overweight) based on thirds of childhood cardiorespiratory fitness level (W/kglbm), by sex & baseline school level

Sex & School Level	PWC_{170} Tertile	% HWM	(n/N)	RR	(95% CI)	Adj. RR[a]	(95% CI)	Adj. RR[b]	(95% CI)
Males									
Primary	T1	47.8	(22/46)	1.0	(ref)	1.0	(ref)	1.0	(ref)
	T2	39.5	(15/38)	0.83	(0.50-1.36)	0.78	(0.50-1.22)	**0.50**	**(0.29-0.82)**
	T3	40.0	(16/40)	0.84	(0.51-1.36)	0.74	(0.47-1.17)	0.57	(0.27-1.20)
					P_{trend} = 0.45		P_{trend} = 0.46		P_{trend} = 0.63
Secondary	T1	37.5	(15/40)	1.0	(ref)	1.0	(ref)	1.0	(ref)
	T2	33.3	(17/51)	0.89	(0.51-1.55)	0.89	(0.48-1.63)	1.16	(0.58-2.34)
	T3	36.8	(21/57)	0.98	(0.58-1.66)	1.05	(0.60-1.85)	1.28	(0.68-2.41)
Females					P_{trend} = 0.99		P_{trend} = 0.78		P_{trend} = 0.80
Primary	T1	75.5	(40/53)	1.0	(ref)	1.0	(ref)	1.0	(ref)
	T2	65.1	(28/43)	0.86	(0.66-1.13)	0.69	(0.46-1.04)	0.64	(0.41-1.01)
	T3	54.8	(17/31)	0.72	(0.51-1.04)	**0.62**	**(0.41-0.96)**	**0.51**	**(0.32-0.81)**
					P_{trend} = 0.05		P_{trend} = 0.06		P_{trend} <0.05
Secondary	T1	53.2	(25/47)	1.0	(ref)	1.0	(ref)	1.0	(ref)
	T2	72.3	(34/47)	1.36	(0.99-1.88)	**1.46**	**(1.02-2.10)**	**1.98**	**(1.31-2.99)**
	T3	64.8	(35/54)	1.22	(0.87-1.70)	1.30	(0.91-1.87)	**1.62**	**(1.02-2.55)**
					P_{trend} = 0.25		P_{trend} = 0.23		P_{trend} = 0.19

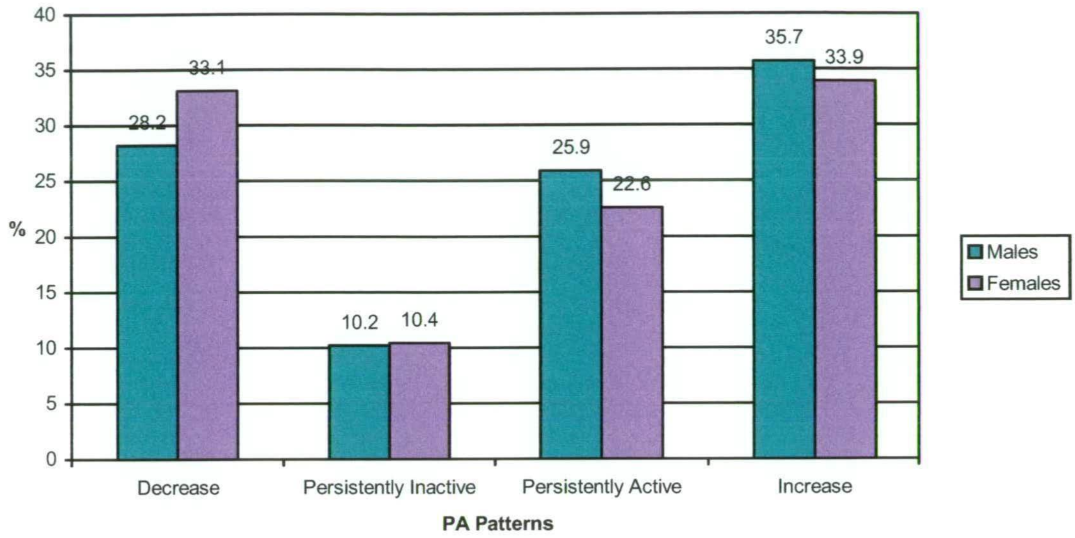
HWM: healthy weight maintainers
[a] Relative risk adjusted for adult fitness (PWC_{170} adjusted for lean body mass)
[b] Relative risk adjusted for adult fitness (PWC_{170} adjusted for lean body mass) plus country of birth, mother's education, highest level of education, marital status & smoking status in males; father's education, highest level of education, marital status & number of children in females

6.5.4 Are Physical Activity Patterns from Childhood to Adulthood Associated with Maintaining a Healthy Weight into Adulthood?

This section first presents findings using Method 1 described earlier to define physical activity patterns (where pattern categories were defined according to the participants' position within thirds of physical activity at baseline and follow-up and indicates the direction of change). Secondly, findings are presented using Method 2, described earlier, to define physical activity change (change in standard deviation z-score which indicates the direction and magnitude of change).

Approximately 30% of participants decreased their activity, slightly more increased their activity, 10% were persistently inactive and 20-25% were persistently active from childhood to adulthood (Figure 32). These proportions are similar to those observed in the Young Finns cohort, which saw 28-30% as decreasingly active, 7-11% as persistently inactive, 32-33% of participants classified as persistently active, and 27-30% as increasingly active (Yang, Telama et al. 2006).

Figure 32: Physical activity patterns from childhood to adulthood, based on self-reported physical activity at baseline & follow-up



When physical activity pattern categories were defined using self-report measures at both time points, no association with healthy weight maintenance was noted (Table 85).

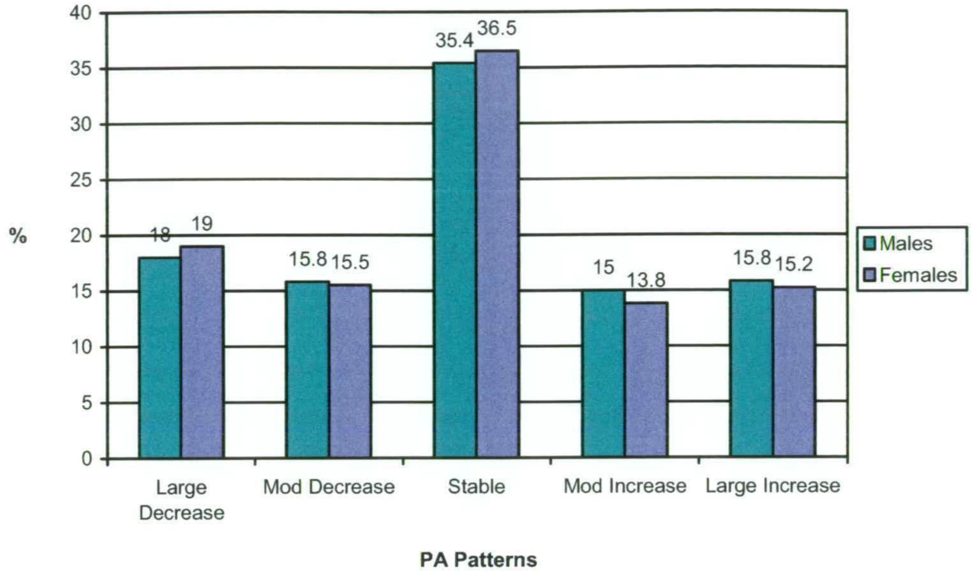
Table 85: Relative risk (RR) of healthy weight maintenance from childhood to adulthood based on patterns of self-reported physical activity from childhood to adulthood in the CDAH follow-up study, by sex & baseline school level

Sex, Child Age & PA Pattern	% HWM	(n/N)	RR	(95% CI)	Adj. RR[a]	(95% CI)	Adj. RR[b]	(95% CI)
Males								
Primary School								
Decreased	44.2	(46/104)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Inactive	41.7	(15/36)	0.94	(0.61-1.47)	0.69	(0.40-1.19)	0.72	(0.39-1.31)
Active	44.1	(37/84)	1.00	(0.72-1.38)	0.98	(0.71-1.35)	1.82	(0.88-1.82)
Increased	45.8	(55/120)	1.04	(0.77-1.39)	0.78	(0.51-1.19)	1.57	(0.70-1.57)
Secondary School								
Decreased	32.6	(31/95)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Inactive	27.3	(9/33)	0.84	(0.45-1.57)	0.61	(0.29-1.28)	0.56	(0.23-1.35)
Active	31.9	(30/94)	0.98	(0.65-1.48)	0.94	(0.62-1.43)	0.86	(0.53-1.42)
Increased	34.5	(41/119)	1.06	(0.72-1.54)	0.81	(0.49-1.34)	0.77	(0.45-1.32)
Females								
Primary School								
Decreased	70.0	(84/120)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Inactive	71.4	(25/35)	1.02	(0.80-1.30)	1.16	(0.76-1.76)	1.07	(0.72-1.58)
Active	60.6	(43/71)	0.87	(0.69-1.08)	0.93	(0.73-1.19)	0.96	(0.73-1.25)
Increased	64.3	(72/112)	0.92	(0.77-1.10)	0.99	(0.73-1.36)	1.03	(0.77-1.38)
Secondary School								
Decreased	63.9	(69/108)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Inactive	67.6	(25/37)	1.06	(0.81-1.38)	1.05	(0.75-1.47)	0.93	(0.64-1.36)
Active	58.2	(46/79)	0.91	(0.72-1.15)	0.91	(0.72-1.15)	0.97	(0.75-1.25)
Increased	64.9	(74/114)	1.02	(0.84-1.24)	1.02	(0.80-1.30)	1.00	(0.75-1.32)

HWM: healthy weight maintainers
[a] Relative risk adjusted for childhood physical activity
[b] Relative risk adjusted for childhood physical activity plus country of birth, mother's education, highest level of education, marital status & smoking status in males; father's education, highest level of education, marital status & number of children in females

Results are now presented using Method 2 described earlier to define physical activity patterns (where pattern categories were defined according to change in standard deviation z-score between baseline and follow-up and indicate the direction and magnitude of change). Approximately 35% of participants remained in the stable activity group, while 15% each showed large decreases, moderate decreases, moderate increases and large decreases (Figure 33).

Figure 33: Self-reported physical activity patterns from childhood to adulthood in the CDAH follow-up study, by sex



Similar to findings when physical activity patterns were defined using Method 1, little association was seen between self-reported physical activity patterns defined using changes in z-score and healthy weight maintenance (Table 86). However, primary school-aged males whose physical activity remained stable or showed a large, but not a moderate, increase were more likely to be healthy weight maintainers than those whose physical activity decreased largely, and there was suggestion of beneficial effects with increasing physical activity in secondary school-aged males and females.

Table 86: Relative risk (RR) of healthy weight maintenance according to change in physical activity z-score from childhood to adulthood in the CDAH follow-up study, by sex & baseline school level

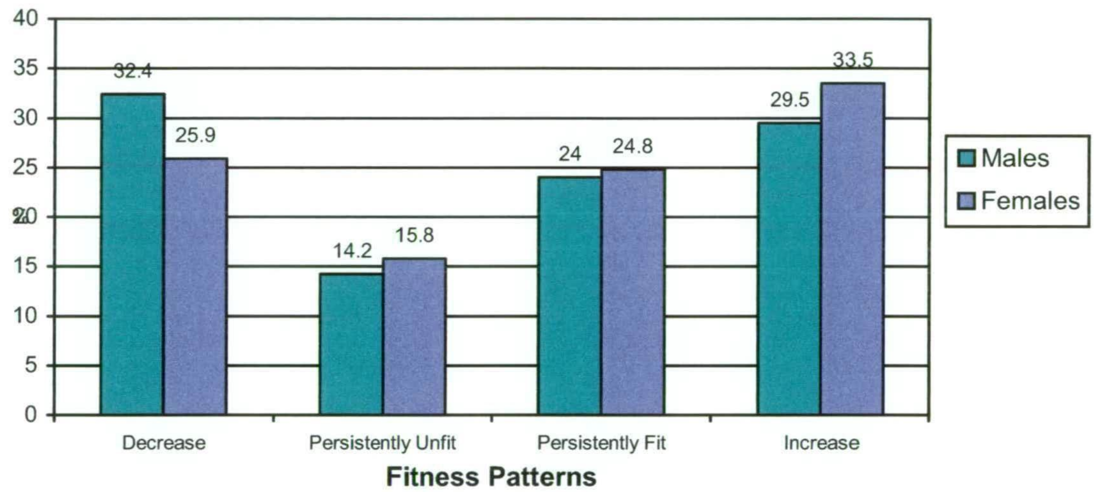
Sex, School Level & PA Pattern	**% HWM**	**(n/N)**	**RR**	**(95% CI)**	**Adj. RR[a]**	**(95% CI)**	**Adj. RR[b]**	**(95% CI)**
Males								
Primary School								
Large Decrease	39.4	(28/71)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Moderate Decrease	45.6	(26/57)	1.16	(0.77-1.73)	1.12	(0.75-1.68)	1.24	(0.79-1.96)
Stable	47.8	(53/111)	1.21	(0.86-1.71)	1.20	(0.84-1.70)	**1.55**	**(1.02-2.34)**
Moderate Increase	34.0	(17/50)	0.86	(0.53-1.40)	0.82	(0.50-1.33)	0.99	(0.53-1.85)
Large Increase	52.7	(29/55)	1.34	(0.91-1.96)	1.26	(0.82-1.93)	**1.79**	**(1.13-2.84)**
				P_{trend} =0.40		P_{trend} = 0.11		P_{trend} = 0.14
Secondary School								
Large Decrease	28.1	(16/57)	1.0		1.0	(ref)	1.0	(ref)
Moderate Decrease	32.7	(17/52)	1.16	(0.66-2.06)	1.15	(0.65-2.03)	1.53	(0.87-2.69)
Stable	32.1	(44/137)	1.14	(0.71-1.85)	1.10	(0.68-1.80)	1.03	(0.60-1.77)
Moderate Increase	38.6	(17/44)	1.38	(0.79-2.40)	1.33	(0.75-2.35)	1.43	(0.80-2.56)
Large Increase	33.3	(17/51)	1.19	(0.67-2.10)	1.18	(0.63-2.21)	1.66	(0.82-3.34)
				P_{trend} = 0.43		P_{trend} = 0.14		P_{trend} <0.05
Females								
Primary School								
Large Decrease	72.1	(44/61)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Moderate Decrease	68.9	(42/61)	0.95	(0.76-1.20)	0.95	(0.74-1.20)	0.84	(0.67-1.04)
Stable	65.6	(78/119)	0.91	(0.74-1.11)	0.90	(0.73-1.13)	0.91	(0.74-1.11)
Moderate Increase	65.2	(30/46)	0.90	(0.70-1.18)	0.89	(0.67-1.19)	0.94	(0.75-1.16)
Large Increase	58.8	(30/51)	0.82	(0.62-1.08)	0.77	(0.55-1.07)	0.85	(0.60-1.21)
				P_{trend} =0.13		P_{trend} = 0.18		P_{trend} = 0.24
Secondary School								
Large Decrease	55.6	(40/72)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Moderate Decrease	68.2	(30/44)	1.23	(0.92-1.64)	1.22	(0.91-1.62)	1.26	(0.90-1.78)
Stable	64.4	(85/132)	1.16	(0.91-1.48)	1.16	(0.91-1.48)	1.23	(0.93-1.64)
Moderate Increase	71.1	(32/45)	1.28	(0.97-1.69)	1.27	(0.95-1.71)	1.36	(0.95-1.95)
Large Increase	60.0	(27/45)	1.08	(0.79-1.48)	1.06	(0.75-1.49)	1.08	(0.72-1.63)
				P_{trend} = 0.40		P_{trend} = 0.35		P_{trend} = 0.30

HWM: healthy weight maintainers
[a] Relative risk adjusted for childhood physical activity
[b] Relative risk adjusted for childhood physical activity plus country of birth, mother's education, highest level of education, marital status & smoking status in males; father's education, highest level of education, marital status & number of children in females

6.5.5 Are Fitness Patterns from Childhood to Adulthood Associated with Maintaining a Healthy Weight into Adulthood?

The following results are presented using Method 1 to categorise cardiorespiratory fitness patterns, where change or stability in cardiorespiratory fitness third at both time points was considered and indicate the direction of change. Similar to physical activity patterns, approximately one third of participants decreased their fitness, another third increased their fitness, while 15% were persistently unfit and one quarter were persistently fit from childhood to adulthood (Figure 34).

Figure 34: Cardiorespiratory fitness patterns from childhood to adulthood, based on a PWC_{170} cycle ergometer test at baseline & follow-up



Cardiorespiratory fitness patterns showed little association with healthy weight maintenance (Table 87). However, females who were primary school-aged at baseline and increased their cardiorespiratory fitness from childhood to adulthood had a significantly increased likelihood of being a healthy weight maintainer, independent of adult cardiorespiratory fitness levels.

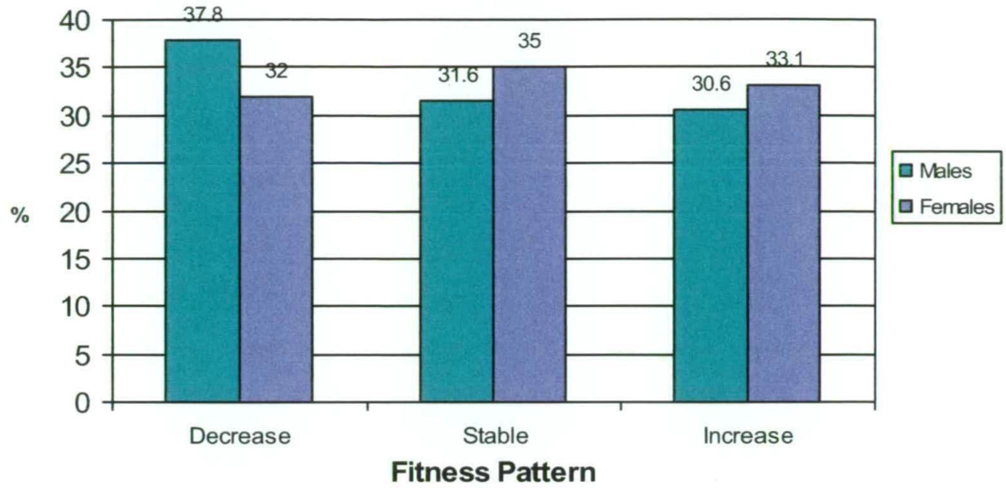
Table 87: Cardiorespiratory fitness patterns (PWC_{170}[a]) & relative risk (RR) of healthy weight maintenance from childhood to adulthood in the CDAH follow-up study, by sex & baseline school level

Sex, Child Age & Fitness Pattern	% HWM	(n/N)	RR	(95% CI)	Adj. RR[b]	(95% CI)	Adj. RR[c]	(95% CI)
Males								
Primary School								
Decreased	30.3	(10/33)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Unfit	50.0	(10/20)	1.65	(0.84-3.25)	2.06	(0.72-5.88)	**6.59**	**(1.05-40.19)**
Fit	46.2	(12/26)	1.52	(0.78-2.96)	1.54	(0.80-2.98)	1.42	(0.63-3.20)
Increased	54.3	(19/35)	1.79	(0.98-3.26)	2.16	(0.92-5.10)	3.73	(0.89-15.66)
				P_{trend} <0.01		P_{trend} <0.05		P_{trend} = 0.05
Secondary School								
Decreased	31.3	(15/48)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Unfit	41.7	(5/12)	1.33	(0.61-2.94)	2.01	(0.57-7.10)	0.80	(0.19-3.41)
Fit	38.2	(13/34)	1.22	(0.67-2.23)	1.24	(0.69-2.25)	0.90	(0.43-1.86)
Increased	35.9	(14/39)	1.15	(0.63-2.08)	1.61	(0.65-3.99)	0.97	(0.35-2.69)
				P_{trend} = 0.50		P_{trend} = 0.66		P_{trend} = 0.61
Females								
Primary School								
Decreased	45.5	(10/22)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Unfit	57.9	(11/19)	1.27	(0.70-2.31)	1.20	(0.57-2.53)	1.69	(0.32-1.55)
Fit	60.7	(17/28)	1.34	(0.77-2.31)	1.35	(0.78-2.33)	1.16	(0.77-1.36)
Increased	85.0	(34/40)	**1.87**	**(1.16-3.01)**	1.83	(0.98-3.42)	**2.23**	**(1.47-5.00)**
				P_{trend} <0.01		P_{trend} <0.01		P_{trend} <0.01
Secondary School								
Decreased	68.6	(24/35)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Unfit	60.0	(9/15)	0.88	(0.55-1.40)	1.00	(0.48-2.06)	0.46	(0.25-0.86)
Fit	83.9	(26/31)	1.22	(0.93-1.61)	1.21	(0.96-1.53)	1.29	(0.99-1.69)
Increased	55.0	(22/40)	0.80	(0.56-1.15)	0.79	(0.52-1.21)	0.41	(0.23-0.72)
				P_{trend} = 0.31		P_{trend} = 0.17		P_{trend} = 0.06

HWM: healthy weight maintainers
[a] PWC_{170} adjusted for lean body mass
[b] Relative risk adjusted for childhood fitness (PWC_{170} adjusted for lean body mass)
[c] Relative risk adjusted for childhood fitness (PWC_{170} adjusted for lean body mass) plus country of birth, mother's education, highest level of education, marital status & smoking status in males; father's education, highest level of education, marital status & number of children in females

When cardiorespiratory fitness patterns were assessed using change in standard deviation z-scores (indicating the direction and magnitude of change), approximately 30-35% saw a decrease in fitness, remained stable or increased fitness (Figure 35).

Figure 35: Cardiorespiratory fitness (PWC_{170}) patterns from childhood to adulthood in the CDAH follow-up study, by sex



Similar to physical activity patterns, primary school aged participants whose cardiorespiratory fitness remained stable or increased were more likely to be healthy weight maintainers than those whose cardiorespiratory fitness decreased (Table 88). This observation persisted after adjustment for baseline fitness and sociodemographic factors.

Table 88: Relative risk (RR) of healthy weight maintenance according to change in cardiorespiratory fitness (PWC_{170}) z-score from childhood to adulthood in the CDAH follow-up study, by sex & baseline school level

Sex, School Level & Fitness Pattern	% HWM	(n/N)	RR	(95% CI)	Adj. RR[a]	(95% CI)	Adj. RR[b]	(95% CI)
Males								
Primary School								
Decrease	33.3	(15/45)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Stable	37.9	(11/29)	1.14	(0.61-2.12)	1.22	(0.63-2.38)	1.77	(0.98-3.20)
Increase	62.5	(25/40)	**1.88**	**(1.16-3.02)**	**2.03**	**(1.16-3.56)**	**2.30**	**(1.21-4.38)**
				P_{trend} <0.01		P_{trend} <0.05		P_{trend} = 0.08
Secondary School								
Decrease	31.4	(16/51)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Stable	37.8	(17/45)	1.20	(0.69-2.09)	1.28	(0.71-2.31)	1.10	(0.54-2.22)
Increase	37.8	(14/37)	1.21	(0.68-2.15)	1.29	(0.69-2.42)	1.30	(0.63-2.65)
				P_{trend} = 0.51		P_{trend} = 0.66		P_{trend} = 0.61
Females								
Primary School								
Decrease	33.3	(9/27)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Stable	65.0	(26/40)	**1.09**	**(1.09-3.48)**	**1.93**	**(1.07-3.51)**	**2.25**	**(1.34-3.79)**
Increase	88.1	(37/42)	**1.53**	**(1.53-4.56)**	**2.62**	**(1.51-4.56)**	**2.66**	**(1.46-4.84)**
				P_{trend} <0.01		P_{trend} <0.01		P_{trend} <0.01
Secondary School								
Decrease	70.5	(31/44)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Stable	70.0	(28/40)	0.99	(0.75-1.31)	1.00	(0.76-1.32)	0.91	(0.70-1.18)
Increase	59.5	(22/37)	0.84	(0.61-1.17)	0.92	(0.65-1.31)	0.70	(0.46-1.05)
				P_{trend} = 0.31		P_{trend} = 0.17		P_{trend} = 0.06

HWM: healthy weight maintainers
[a] Relative risk adjusted for childhood fitness
[b] Relative risk adjusted for childhood fitness plus country of birth, mother's education, highest level of education, marital status & smoking status in males; father's education, highest level of education, marital status & number of children in females

6.6 Discussion

The aim of this chapter was to examine the longitudinal relationship between physical activity, cardiorespiratory fitness and healthy weight maintenance from childhood into adulthood. The findings suggest that primary school aged children who increased or maintained their relative cardiorespiratory fitness levels between childhood and adulthood were more likely to maintain a healthy weight over this period than those whose relative physical activity or cardiorespiratory fitness decreased. This finding was consistent between the two methods used to define cardiorespiratory fitness patterns. The findings suggest that the primary school years may be more important than the secondary school years for establishing cardiorespiratory fitness patterns that are related to maintaining a healthy weight into adulthood.

It is possible that the different associations seen across different school levels in the current study are because healthy weight may be more prevalent in the younger cohort (aged approximately 26-30 years at follow-up). While the most recent Australian overweight and obesity data do not present results in age strata small enough to make direct comparisons with the current study, increasing prevalence of overweight and obesity in both males and females from age 25-34 years until age 65-74 years in males and 55-64 years in females have been observed (Cameron, Welborn et al. 2003). In the current study, there were more healthy weight maintainers in the younger cohort of males (47.2% maintainers who were primary school-aged at baseline versus 32.3% maintainers who were secondary school-aged at baseline), but the difference was not as large for females (67.1% versus 62.9%).

Alternatively, it is plausible that associations were observed in those primary school-aged at baseline but not those secondary school-aged at baseline because of altered behavioural and physiological characteristics during puberty and adolescence. For instance, it is well documented that girls' physical activity decreases during adolescence. Physiological changes during this time may influence classification of weight status and cardiorespiratory fitness patterns, therefore masking true associations. Younger children on the other hand may show more consistent behavioural and physiological characteristics that are not yet influenced by changes associated with maturation.

While no other published reports have examined childhood predictors of healthy weight maintenance, a small number of studies have assessed physical activity patterns as a predictor of adult obesity, with similar findings to the current study. The Young Finns, British Birth Cohort and Northern Finland Birth Cohort studies found that females who were relatively inactive or who decreased their relative physical activity had less favourable adiposity outcomes (Tammelin, Laitinen et al. 2004; Parsons, Manor et al. 2006; Yang, Telama et al. 2006). The Northern Finland Birth Cohort study and the Danish Youth and Sports Study (Hasselstrom, Hansen et al. 2002) saw associations between decreasing physical activity or persistent physical inactivity and less favourable adiposity outcomes in males. None of these reports presented results stratified by age or an indicator of age such as school level, which makes direct comparisons difficult and makes it impossible to determine whether the age differences observed in the current study are consistent with previous work.

To this author's knowledge, only one other study has examined the association between cardiorespiratory fitness patterns from childhood to adulthood and adult weight status. Similar to the current study, the Danish Youth and Sports Study found that changes in absolute fitness (maximal oxygen uptake estimated from a cycle ergometer test) were negatively associated with adult waist girth in males and adult percent body fat in both males and females (Hasselstrom, Hansen et al. 2002). These consistent findings are interesting because although both studies used the same mode of testing – a cycle ergometer test – the Danish Youth and Sports Study used a direct measure of maximal oxygen uptake, while the current study used a submaximal estimate of aerobic power.

The findings from the current study suggest that childhood physical activity alone did not increase the prevalence of healthy weight maintenance from childhood into adulthood. This supports previous findings from the Northern Ireland Young Hearts study (Boreham, Twisk et al. 2002), which used a similar measure of childhood physical activity to the current study, the Leuven Longitudinal Study (Lefevre, Philippaerts et al. 2002), where childhood physical activity had little direct influence on adult weight status, and the Amsterdam Growth and Health Longitudinal Study, where childhood physical activity was not associated with the sum of four skinfolds or the waist to hip ratio (although some inconsistent associations were seen with waist circumference) (Twisk, Kemper et al. 2002). While no association was seen in this chapter between childhood physical activity and adult outcomes, higher cardiorespiratory fitness levels in primary school aged children were associated with a higher prevalence of healthy weight maintenance, a finding similar to that observed in the Young Hearts study, the Amsterdam Growth and Health Longitudinal study (Twisk, Kemper et al. 2002) and the Danish Youth and Sports Study (females only), where the prevalence of overweight or obesity in adults was lower in children who had higher levels of cardiorespiratory fitness.

When assessing physical activity and cardiorespiratory fitness patterns across the two time points, it was noted with interest that those in the stable or persistently inactive or unfit categories were commonly more likely to maintain a healthy weight from childhood into adulthood than those whose physical activity or cardiorespiratory fitness was categorised as decreasing. This finding was similar to that observed in the Young Finns cohort, where females who decreased their physical activity were at higher risk for overweight and obesity than those who were persistently inactive (Yang, Telama et al. 2006). A similar finding was seen in the Northern Finland Birth Cohort, where becoming inactive, but not persistent inactivity, was associated with an increased odds of overweight and obesity in males and severe abdominal obesity in females (Tammelin, Laitinen et al. 2004). While this finding may appear surprising, it is plausible that participants in this group have from an early age established ways to regulate their energy consumption to compensate for their lower physical activity levels, whereas those who move to a lower physical activity level may not adequately reduce their energy intake, with the overall result being a gain in weight. For example, those who throughout their life do little physical activity or have low cardiorespiratory levels may consume an amount of food that ensures their weight remains stable. However, those whose physical activity or cardiorespiratory fitness levels have decreased may continue to consume energy at the same level they did when they were expending higher levels of energy. Once they decrease their energy expenditure, it is plausible that they do not institute parallel decreases in their energy intake, which would explain why they are less likely to maintain a healthy weight. While this theory seems plausible, dietary data were not available in this or the Finnish analyses so it is therefore unknown whether this hypothesis is likely to be true.

While child and adult sociodemographic factors were related to healthy weight maintenance, the associations were weak and differed according to sex. Being a male born outside Australia and having a university-educated mother were the two childhood sociodemographic factors that predicted healthy weight maintenance in males, while having a university-educated father was the only childhood sociodemographic predictor in females, independently of adult sociodemographic factors. In adulthood, being tertiary educated and not being in a de facto relationship (i.e. being married or single) was associated with being a healthy weight maintainer in both males and females, while smoking in males and having fewer children in females were associated with healthy weight maintenance. In 1989, Sobal and Stunkard published a review of 144 studies from all around the world spanning 45 years and found that irrespective of the measures of SES and the measures of fatness, there existed a consistent negative association between SES and obesity in women (Sobal and Stunkard 1989). Less consistent findings were observed for men and children. However, most of the studies included in this review were cross-sectional. In the more recent review of childhood predictors of adult obesity, Parsons and colleagues examined data from twelve longitudinal studies with a duration of 10-55 years (Parsons, Manor et al. 2006). Four out of five studies in females, eight out of nine studies in males and three out of four studies in males and females combined demonstrated that children from the lower socioeconomic groups tended to be the fattest adults. The current study did not find such strong or consistent relationships between childhood sociodemographic factors and healthy weight maintenance. Interestingly, the two childhood factors that were associated with healthy weight maintenance were mother's and father's education in males and females, respectively, even though these variables were retrospectively recalled. While occupation might change considerably over time, education is thought to be relatively stable (Parsons, Manor et al. 2006), so it is not surprising that parental education, but not occupation, showed an association with the outcome.

A major limitation of this study was that no information was available on physical activity, cardiorespiratory fitness or weight status during the time between baseline data collection in childhood and follow-up data collection in adulthood. It is possible that during this 20 year period each of these factors could have changed a number of times in a number of directions. The data collected at the two time points may not necessarily reflect the participants' usual behaviours and characteristics over the past 20 years. However, a number of prospective studies with repeated measures have shown weight status, physical activity and cardiorespiratory fitness to be relatively stable from childhood into adolescence and adolescence into adulthood (Twisk, Kemper et al. 1995; Power, Lake et al. 1997). While adjustments were made for factors that may have influenced these behaviours and characteristics, such as smoking, area-level socioeconomic status, parental education, parental smoking and parental physical activity at baseline, and highest level of education, marital status, number of children (females) and smoking at follow-up, it is plausible that unmeasured confounding may explain some of the findings observed.

A major strength of this study was its large size and long period of follow-up. These advantageous elements enabled a prospective examination of the factors that influence healthy weight maintenance from childhood into adulthood. In addition, the large sample size enabled stratification by sex and school level, allowing for examination of associations amongst different subgroups. Furthermore, few studies of this size and duration have objectively measured cardiorespiratory fitness, which allowed for comparison between the physical activity and cardiorespiratory fitness measures. This is also one of the first studies to examine the role of physical activity and cardiorespiratory fitness in maintaining a healthy weight from childhood into adulthood.

By investigating factors associated with healthy weight maintenance, the findings have highlighted that cardiorespiratory fitness patterns appear to play a small role in healthy weight maintenance over time. While change in relative cardiorespiratory fitness measured at two points in time was associated with the likelihood of maintaining a healthy weight, findings were inconsistent between younger and older participants, suggesting that the timing of fitness measurements may be important for predicting healthy weight. This chapter has provided valuable insights into the physical activity and cardiorespiratory fitness patterns of those who maintain a healthy weight from childhood to adulthood, compared with those who become overweight. However, there is still much to learn about the personal, social, environmental and genetic factors that may also play an important role in maintaining a healthy weight from childhood to adulthood.

6.7 Summary

What is already known about this topic?

- There is conflicting evidence about the role of childhood physical activity and fitness in determining adult weight status, and about the role of physical activity and fitness patterns over time
- Examining factors associated with healthy weight maintenance may provide valuable insights for overweight prevention strategies
- No published reports have examined physical activity and fitness as predictors of healthy weight maintenance from childhood into adulthood

What was done to learn more?

- 2,053 young Australian adults (aged 26-36 years) were surveyed as part of the Childhood Determinants of Adult Health (CDAH) follow-up study
- Participants completed a physical activity questionnaire in childhood, the IPAQ-L in adulthood, and had their fitness, height and weight measured at both time points
- Healthy weight maintainers were those who were healthy weight at both time points, while gainers were healthy weight children who became overweight
- Log binomial regression was used to estimate the likelihood of being a healthy weight maintainer according to childhood physical activity and fitness, and according to physical activity and cardiorespiratory fitness patterns over time

What were the key results?

- There was little consistent evidence that childhood physical activity or fitness was associated with being a healthy weight maintainer
- Increasing fitness was associated with an increased likelihood of healthy weight maintenance in those primary school-aged at baseline, compared with decreasing fitness (RR 2.30, 95% CI: 1.21-4.38 in males; RR 2.66, 95% CI: 1.46-4.84 in females)
- Younger participants whose fitness remained stable over time were more likely to be healthy weight maintainers than those whose fitness decreased (RR 1.77, 95% CI: 0.98-3.20 in males; RR 2.25, 95% CI: 1.34-3.79 in females)

What does this study add?

- Childhood physical activity and fitness appear to have little influence on healthy weight maintenance over time
- Stable or increasing fitness levels increase the likelihood of healthy weight maintenance, particularly in younger participants
- Change or stability of physical activity and fitness between childhood and adulthood appeared to play only a minor role in healthy weight maintenance

CHAPTER 7 – SUMMARY, LIMITATIONS & FUTURE DIRECTIONS

7.1 The Importance of Physical Activity & Fitness in Maintaining a Healthy Weight

Overweight and obesity are significant public health concerns. In Australia, the prevalence of overweight and obesity significantly increased over the past two decades in both children and adults. Overweight and obesity increase the risk for a number of serious health problems, including coronary heart disease, type 2 diabetes, stroke and all-cause mortality (Visscher and Seidell 2001), and there is some evidence to suggest that being obese as a child confers additional health risk in adulthood (Lauer and Clarke 1989; Srinivasan, Bao et al. 1996). As well as physical health effects, overweight and obesity are associated with psychological and social issues such as stigma, low self-esteem, reduced mobility and a generally poorer quality of life (Seidell 2005). Financial costs of obesity in Australia were estimated at $3.8 billion in 2005, including $1.7 billion in productivity costs, $873 million in health system costs, and $804 million in carer costs (Access Economics 2006).

While obesity appears to pose more of a health threat than overweight, being overweight is a significant predictor of becoming obese (Power, Lake et al. 1997). It is therefore important to intervene as early as possible to prevent this transition. Some authors have suggested that examining the behaviours and characteristics of healthy weight individuals may provide important insights for overweight and obesity prevention (Parsons, Power et al. 1999). However, very little research to date has investigated factors associated with being a healthy weight or with maintaining a healthy weight, without prior weight loss intervention. Similarly, no published reports have examined predictors of healthy weight maintenance over an extended period of time, or from childhood into adulthood.

There is evidence to suggest that while overweight and obesity are increasing, there has been a concurrent decline in physical activity, both in Australia and internationally. Physical activity is an important element of the energy balance equation and is the only easily modified component of energy expenditure. Little is currently known about the physical activity and cardiorespiratory fitness levels of individuals who maintain a healthy weight over time. These individuals are of interest because they appear to have developed a "resiliency" to overweight and obesity. Understanding how these groups successfully maintain a healthy weight in the current obesogenic environment may provide useful insights for overweight prevention strategies. For instance, are they more active or fitter than those who become overweight? Do their physical activity and fitness patterns change or do they remain stable? This thesis aimed to examine the importance of physical activity and cardiorespiratory fitness in maintaining a healthy weight by examining four key research questions using data collected from a prospective cohort of 8,498 Australian children aged 7-15 years, 2,053 of whom were followed up as young adults aged 26-36 years during 2004-5.

7.2 Summary of Results and Interpretation of Findings

The analyses in this thesis were guided by a framework adapted from a model proposed by Blair and colleagues (1989), whereby the complex, multi-directional relationships between physical activity, fitness and health in childhood and adulthood are described. This model provided a useful framework upon which to base analyses in this thesis, and would be well-utilised by researchers who wish to examine similar relationships in future investigations. This section provides a summary of the results and discussion of the possible interpretations of findings from each chapter.

7.2.1 Are Active, Fit Children More likely to be a Healthy Weight than Less Active Children?

The cross-sectional association between children's physical activity, cardiorespiratory fitness and weight status was examined, the only study to do so in a large, representative sample of Australian children. Additionally, this study used a measure of physical activity that collected information on both duration and frequency, and measured cardiorespiratory fitness objectively on a large subsample, both of which are uncommon in larger studies. As found in many previous investigations that have used self-reported measures of physical activity, physically active children were no more likely to be a healthy weight than less active children. However, healthy weight children showed more favourable cardiorespiratory fitness levels than overweight children, an observation that has also been noted previously. This finding suggests that the physical attribute, cardiorespiratory fitness, shows stronger associations with weight status in children and adolescents than the behaviour, physical activity, an important consideration for researchers wanting to examine the physical activity-fitness-weight status relationship. Possibly, the type and duration of children's physical activity is not as important for predicting weight status as is the level of cardiorespiratory fitness achieved. Alternatively, it is also plausible that measures of cardiorespiratory fitness better "capture" physical activity behaviours than self-reported measures, and also reflect genetic factors which have an important influence on cardiorespiratory fitness. It is likely that both of these factors contribute to explaining the findings. These cross-sectional results suggest that developing strategies that aim to increase children's physical activity and cardiorespiratory fitness may have some success for overweight and obesity prevention, although given the modest associations observed, it seems likely that focusing efforts on creating *energy balance* will be central for healthy weight at this age. Investigating ways to promote fitness-enhancing (vigorous) activities in a manner that is appealing to children and adolescents will be an important step for obesity prevention strategies.

7.2.2 Are Active, Fit Adults More likely to be a Healthy Weight than Less Active Adults?

The cross-sectional association between adults' physical activity, cardiorespiratory fitness and healthy weight was examined. This was the largest study to date to employ pedometer measures of physical activity, and few studies have had the added strength of being able to examine cardiorespiratory fitness in the same sample. While higher levels of physical activity and cardiorespiratory fitness were associated with an increased likelihood of being a healthy weight in both sexes, the association was stronger in women. It is plausible that the physical activity measures used were better able to capture women's physical activity. Interestingly, physical activity showed a stronger relationship with healthy weight than did cardiorespiratory fitness in both men and women. This was a surprising finding in contrast to previous research, although other studies have mostly used self-reported measures of physical activity. An objective measure of physical activity, a pedometer, was employed in the current study, possibly explaining these differences. In the current study, no association was seen in either men or women between healthy weight and self-reported physical activity, likely because of the instrument used or the age of participants. Differences were observed in associations when different measures of adiposity were used to define healthy weight in men. When BMI was used, no associations with either physical activity or cardiorespiratory fitness were evident, but when waist circumference was used to define healthy weight, associations became apparent, suggesting that waist circumference may better discriminate those with or without excess body fatness, particularly central adiposity.

7.2.3 Do Adiposity, Physical Activity and Cardiorespiratory Fitness Track from Childhood to Adulthood?

First, the tracking of adiposity from childhood into adulthood was examined. This is one of the first studies to examine tracking of weight status using recently developed age- and sex-specific cutpoints for overweight and obesity in children. Only 35% of healthy weight boys and 65% of healthy weight girls remained healthy weight 20 years later as young adults. Interestingly, while most overweight children became overweight or obese adults, only a small proportion of overweight in adulthood was attributable to overweight in childhood. This finding combined with the nearly identical prevalence of overweight and obesity in each age group at baseline suggests that the onset of overweight occurred in late adolescence or early adulthood. Obesity prevention strategies in childhood are important because overweight and obesity tend to persist into adulthood and very few overweight or obese children become healthy weight adults. The findings suggest that late adolescence and early adulthood – times of significant change and transition – may be key times for overweight and obesity prevention strategies.

Second, the tracking of physical activity and cardiorespiratory fitness from childhood into adulthood was examined. No published reports have examined tracking of physical activity and cardiorespiratory fitness in Australia in such a large sample, and few other similar studies exist in the world. It is also one of very few studies that have had the ability to simultaneously examine the tracking of objectively measured cardiorespiratory fitness. As seen in other prospective cohort studies, physical activity tracked poorly while cardiorespiratory fitness tracked modestly from childhood into adulthood. Promoting physical activity in childhood with the aim of increasing adult physical activity levels may therefore be ineffective. Low levels of physical activity tracking have been observed in a number of studies spanning different time periods, different countries, using different measures and employing different analytical techniques. While there is no disputing the short term social and health benefits of physical activity, there is little evidence that physically active children will become physically active adults. Unlike cardiorespiratory fitness which is influenced by physical activity, genetics and morphology, physical activity is a behaviour that is significantly influenced by personal, social and environmental factors. It is therefore not surprising that little association between child and adult physical activity is observed in this and other studies, while cardiorespiratory fitness tends to track more strongly.

7.2.4 Are Active Children More Likely to Maintain a Healthy Weight from Childhood to Adulthood?

The role of physical activity and cardiorespiratory fitness in maintaining a healthy weight from childhood into adulthood was examined. No previous research has examined childhood physical activity or cardiorespiratory fitness as predictors of healthy weight maintenance. More active children were no more likely to be healthy weight maintainers than less active children, nor were fitter children more likely to be healthy weight maintainers than less fit children. While childhood physical activity and fitness alone seemed to have little impact on healthy weight maintenance, fitness patterns over time played a more important role. Younger participants whose relative fitness remained stable or increased from childhood to adulthood were more likely to maintain a healthy weight than those whose relative fitness decreased over time. Again, while there is no disputing the beneficial effects of physical activity in the short term, the findings from this investigation suggest that promoting physical activity to children as a way to reduce future adult overweight may have limited success. This must be considered when planning the long term goals of obesity prevention strategies targeting children. While physical activity and cardiorespiratory fitness patterns over time appear to play a role in maintaining a healthy weight, particularly in younger groups, personal, social, environmental and genetic factors are likely to play a significant role. There is still much to learn about the personal, social, environmental and genetic characteristics of those who manage to maintain a healthy weight, despite the current obesity-promoting environment.

7.3 Possible Limitations

Like all observational epidemiologic investigations, there were a number of limitations evident in this study which may have influenced findings. These limitations relate to the possibility of selection bias, information bias and potential confounding. It is possible that selection bias exists in this study. Selection bias relates to systematic error in a study that results from the procedures used to select participants and from factors that influence participation (Rothman 2002). However, as detailed in Chapter 5, the minor baseline differences in participants and non-participants are unlikely to significantly impact on the results. Furthermore, as detailed in Chapter 4, the follow-up sample demonstrated a similar prevalence of overweight and obesity to the general Australian population of a similar age, and sociodemographic characteristics did not greatly differ. The comparisons suggested that while the findings from this study may be generalisable, they may not be applicable to those from more disadvantaged socioeconomic groups. It is possible that associations between weight status, physical activity and cardiorespiratory fitness in the current study could be different in those from lower socioeconomic groups. Plausibly, differences in availability and accessibility to physical activity and healthy eating opportunities may result in different associations with weight status, although it is not apparent how or why the biological mechanisms would differ between these groups.

Another form of bias, information bias, may have influenced the findings in this study. Information bias, sometimes referred to as misclassification bias, can occur when information collected about or from participants is erroneous (Rothman 2002). There are a number of instances in this study where information bias may have been present. While at both time-points height and weight were objectively measured by trained data collectors, the use of BMI to categorise participants as healthy weight or overweight has the potential to misclassify some participants, particularly those with a high proportion of lean body mass. The cutpoints used to categorise BMI at both time-points however are well-accepted internationally, make comparisons with other datasets possible and are widely used in research and clinical settings. In addition, for the purposes of the longitudinal components of this study, it was not possible to use another estimate of adiposity, such as waist circumference or per cent body fat derived from skinfold thicknesses, because there is currently no consensus on the best cutpoints to use, particularly for children. To assess whether this potential bias may have affected the results, data were re-analysed using obese ($BMI \geq 30 kg/m^2$) as the comparison group, rather than overweight ($BMI \geq 25 kg/m^2$). Results were similar and sometimes stronger (data not shown), suggesting that if bias was present in the classification of healthy weight and overweight it is likely that estimates would be shifted towards the null, so true effects may have been underestimated.

Information bias may be present in the use of self-reported measures of physical activity, particularly at baseline. At follow-up, valid and reliable self-reported measures were used in conjunction with an objective measure of physical activity (pedometers). Interestingly, cross-sectional associations were seen with adiposity when pedometers were used to estimate physical activity, but not when self-report was used. The limitations of these measures have been discussed previously in the relevant chapters. While it would have been ideal to use an objective measure of physical activity at both time points, pedometers and accelerometers were not commonly used in physical activity research when the baseline data were collected. Again, if a bias was present in the measurement of physical activity, it is likely that this would underestimate associations and shift estimates towards the null.

It is possible that the definitions used to categorise physical activity and cardiorespiratory fitness measures were flawed. For the physical activity measures, categories were created from logically deduced cutpoints that could be easily adapted for public health messages. Because of the lack of accepted cutpoints for cardiorespiratory fitness cutpoints, these categories were based on the distribution of data (i.e. thirds, quarters). While either of these approaches may lack the sensitivity to detect small differences in the outcome, comparisons between the lowest groups with each of the other groups should enable a clear indication of whether differences exist.

A third possible limitation of this study is the potential for confounding, where the effect of the exposure is mixed together with the effect of another variable leading to bias (Rothman 2002). While every attempt was made to measure and make appropriate adjustments for possible confounding factors, such as childhood SES, adult occupation, highest level of education, smoking, marital status and number of children (females), it is possible that other factors that were not measured may have confounded the associations examined. For instance, adjustments were not made for the presence of pre-existing health conditions that may impact independently on physical activity and on weight status. However, this study was conducted in a sample of young, healthy Australian adults so it seems unlikely that chronic illness would influence the overall findings. Additionally, a major limitation of this study was that no information was available about the 20-year period in between baseline measures in childhood and follow-up measures in young adulthood. It is possible that during this time there could have been a number of fluctuations in physical activity, cardiorespiratory fitness and weight status. Similarly, the periods from childhood into adolescence and adolescence into adulthood are times of significant transition and many complex factors may impact on behaviours during this time. For instance, completion of schooling, tertiary education, entry to the workforce, marriage, and starting a family are all momentous life events that may significantly impact on an individual's physical activity, fitness and weight status.

7.4 Future Directions

This thesis has contributed to the body of evidence examining the cross-sectional and longitudinal relationships between physical activity, cardiorespiratory fitness and adiposity in children and adults. By examining the role of physical activity and cardiorespiratory fitness in healthy weight maintenance, this thesis has provided a valuable insight into the behaviours of those individuals who manage to successfully avoid becoming overweight over time. The findings have implications for future physical activity and adiposity research, and for physical activity promotion and obesity prevention strategies that target children, adolescents and young adults. Based on the findings from this thesis, it is important for future research to investigate:

- the sociodemographic, biological and behavioural factors associated with the maintenance of a healthy weight from childhood to adulthood
- the sociodemographic, biological and behavioural factors associated with the onset of overweight and obesity during late adolescence and early adulthood;
- the role of energy intake over time in the maintenance of a healthy weight;
- innovative approaches to the targeting of overweight prevention strategies for older adolescents and young adults;
- the factors associated with becoming a healthy weight adult if overweight or obese as a child;
- the personal and social factors associated with change and stability in physical activity and cardiorespiratory fitness;
- why physical activity and cardiorespiratory fitness show stronger relationships with healthy weight in women than in men;
- why objective measures of physical activity show a stronger associations with healthy weight than cardiorespiratory fitness;
- the relative merits of using BMI and waist circumference to define weight status when assessing associations with physical activity and fitness, particularly in men;
- sex differences in the relationship between sedentary behaviours and physical activity and inactivity
- the longitudinal relationship between physical activity and weight status in children using objective measures of physical activity.

7.5 Conclusion

While physical activity and cardiorespiratory fitness showed cross-sectional associations with healthy weight, particularly in adulthood, they appeared to play a limited role in the maintenance of a healthy weight over time in this contemporary cohort of young Australians. Targeting overweight prevention interventions towards those who are currently healthy weight is warranted, because of the common transition to overweight and obesity. Multifaceted strategies that focus on the promotion of *energy balance* by encouraging physical activity, discouraging sedentary behaviours and discouraging excessive energy intake are likely to have most impact on the overweight and obesity epidemic in Australia. Determining the best times to intervene and the most appropriate strategies will be an important challenge on the road to reducing the prevalence of overweight and obesity in Australia.

REFERENCES

Aaron, D. J., A. M. Kriska, et al. (1993). "The epidemiology of leisure physical activity in an adolescent population." Med Sci Sports Exerc **25**(7): 847-53.

Abbott, R. A. and P. S. Davies (2004). "Habitual physical activity and physical activity intensity: their relation to body composition in 5.0-10.5-y-old children." Eur J Clin Nutr **58**(2): 285-91.

Access Economics (2006). The economic costs of obesity: a report by Access Economics Pty Ltd to Diabetes Australia. Australia, Diabetes Australia.

AIHW (2006). AIHW Analysis of the 1980, 1983 and 1989 Risk Factor Prevalence Surveys, 1995 National Nutrition Survey and 1999-2000 Australian Diabetes, Obesity and Lifestyle Study, AIHW. **2006**.

Ainsworth, B., H. J. Montoye, et al. (1994). Methods of Assessing Physical Activity During Leisure and Work. Physical Activity, Fitness and Health: International proceedings and consensus statement. C. Bouchard, R. J. Shephard and T. Stephens. Champaign, Human Kinetics.

Ainsworth, B. E., W. L. Haskell, et al. (2000). "Compendium of physical activities: an update of activity codes and MET intensities." Med Sci Sports Exerc **32**(9 Suppl): S498-504.

Albanes, D., A. Blair, et al. (1989). "Physical activity and risk of cancer in the NHANES I population." Am J Public Health **79**(6): 744-50.

Andersen, L. B. and J. Haraldsdottir (1993). "Tracking of cardiovascular disease risk factors including maximal oxygen uptake and physical activity from late teenage to adulthood. An 8-year follow-up study." J Intern Med **234**(3): 309-15.

Andersen, R. E., C. J. Crespo, et al. (1998). "Relationship of physical activity and television watching with body weight and level of fatness among children: results from the Third National Health and Nutrition Examination Survey." JAMA **279**(12): 938-42.

Armstrong, T., A. Bauman, et al. (2000). Physical activity patterns of Australian adults: results of the 1999 National Physical Activity Survey. Canberra, Australian Institute of Health and Welfare.

Australian Bureau of Statistics (2000). Children's participation in cultural and leisure activities. Canberra, Australian Bureau of Statistics.

Australian Bureau of Statistics (2001). Australian Census of Population & Housing 2001 Expanded Community Profile. Canberra, Australian Bureau of Statistics.

Australian Bureau of Statistics (2003). Births, Australia. Canberra, Australian Bureau of Statistics.

Australian Department of Health and Aged Care (1999). National physical activity guidelines for Australians. Canberra, Department of Health and Aged Care.

Australian Department of Health and Aging (2004). Australia's Physical Activity Recommendations for Children and Young People. Canberra, Australian Department of Health and Aging.

Australian Institute of Health & Welfare (1999). Heart, Stroke and Vascular Diseases: Australian Facts 2001. Canberra, Australian Institute of Health and Welfare, National Heart Foundation of Australia, National Stroke Foundation of Australia.

Australian Sports Commission (2004). Participation in Exercise, Recreation and Sport: Annual Report 2004. Canberra, Australian Sports Commission.

Baik, I., A. Ascherio, et al. (2000). "Adiposity and mortality in men." Am J Epidemiol **152**(3): 264-71.

Ball, E. J., J. O'Connor, et al. (2001). "Total energy expenditure, body fatness, and physical activity in children aged 6-9 y." Am J Clin Nutr **74**(4): 524-8.

Ball, K., W. Brown, et al. (2002). "Who does not gain weight? Prevalence and predictors of weight maintenance in young women." Int J Obes Relat Metab Disord **26**(12): 1570-8.

Ball, K., N. Owen, et al. (2001). "Associations of physical activity with body weight and fat in men and women." Int J Obes Relat Metab Disord **25**(6): 914-9.

Bao, W., S. R. Srinivasan, et al. (1996). "Usefulness of childhood low-density lipoprotein cholesterol level in predicting adult dyslipidemia and other cardiovascular risks. The Bogalusa Heart Study." Arch Intern Med **156**(12): 1315-20.

Bao, W., S. A. Threefoot, et al. (1995). "Essential hypertension predicted by tracking of elevated blood pressure from childhood to adulthood: the Bogalusa Heart Study." Am J Hypertens **8**(7): 657-65.

Baquet, G., E. van Praagh, et al. (2003). "Endurance training and aerobic fitness in young people." Sports Med **33**(15): 1127-43.

Baranowski, T., C. Bouchard, et al. (1992). "Assessment, prevalence, and cardiovascular benefits of physical activity and fitness in youth." Med Sci Sports Exerc **24**(6 Suppl): S237-47.

Barengo, N. C., A. Nissinen, et al. (2002). "Twenty-five-year trends in physical activity of 30- to 59-year-old populations in eastern Finland." Med Sci Sports Exerc **34**(8): 1302-7.

Barnekow-Bergkvist, M., G. Hedberg, et al. (1996). "Physical activity pattern in men and women at the ages of 16 and 34 and development of physical activity from adolescence to adulthood." Scand J Med Sci Sports **6**(6): 359-70.

Bassett, D. R., Jr. (2000). "Validity and reliability issues in objective monitoring of physical activity." Res Q Exerc Sport **71**(2 Suppl): S30-6.

Bassett, D. R., Jr., B. E. Ainsworth, et al. (1996). "Accuracy of five electronic pedometers for measuring distance walked." Med Sci Sports Exerc **28**(8): 1071-7.

Batty, G. D., D. A. Lawlor, et al. (2005). "Accuracy of adults' recall of childhood social class: findings from the Aberdeen children of the 1950s study." J Epidemiol Community Health **59**(10): 898-903.

Bauman, A., I. Ford, et al. (2001). Trends in population levels of reported physical activity in Australia, 1997, 1999 and 2000. Canberra, Australian Sports Commission.

Bauman, A. and D. Merom (2002). "Measurement and surveillance of physical activity in Australia - an introductory guide." Australasian Epidemiologist **9**(2): 2-6.

Bauman, A. and N. Owen (1991). "Habitual physical activity and cardiovascular risk factors." Med J Aust **154**(1): 22-8.

Benichou, J. and M. H. Gail (1990). "Variance calculations and confidence intervals for estimates of the attributable risk based on logistic models." Biometrics **46**(4): 991-1003.

Berkey, C. S., H. R. Rockett, et al. (2000). "Activity, dietary intake, and weight changes in a longitudinal study of preadolescent and adolescent boys and girls." Pediatrics **105**(4): E56.

Berkey, C. S., H. R. Rockett, et al. (2003). "One-year changes in activity and in inactivity among 10- to 15-year-old boys and girls: relationship to change in body mass index." Pediatrics **111**(4 Pt 1): 836-43.

Berlin, J. A. and G. A. Colditz (1990). "A meta-analysis of physical activity in the prevention of coronary heart disease." Am J Epidemiol **132**(4): 612-28.

Bernstein, M. S., M. C. Costanza, et al. (2004). "Association of physical activity intensity levels with overweight and obesity in a population-based sample of adults." Prev Med **38**(1): 94-104.

Beunen, G. P., R. M. Malina, et al. (1992). "Physical activity and growth, maturation and performance: a longitudinal study." Med Sci Sports Exerc **24**(5): 576-85.

Blair, S. N., D. G. Clark, et al. (1989). Exercise & Fitness in Childhood: Implications for a Lifetime of Health. Perspectives in Exercise Scient & Sports Medicine: Youth, Exercise & Sport. C. V. Gisolfi and D. R. Lamb. USA, Cooper Publishing Group. **2:** 401-22.

Blair, S. N. and M. J. LaMonte (2006). "Commentary: current perspectives on obesity and health: black and white, or shades of grey?" Int J Epidemiol **35**(1): 69-72; discussion 81-2.

Bogaert, N., K. S. Steinbeck, et al. (2003). "Food, activity and family--environmental vs biochemical predictors of weight gain in children." Eur J Clin Nutr **57**(10): 1242-9.

Booth, M. L., T. Chey, et al. (2003). "Change in the prevalence of overweight and obesity among young Australians, 1969-1997." Am J Clin Nutr **77**(1): 29-36.

Booth, M. L., P. Macaskill, et al. (1998). "Methods of the NSW Schools Fitness and Physical Activity Survey, 1997." J Sci Med Sport **1**(2): 111-24.

Booth, M. L., A. D. Okely, et al. (2002). "Epidemiology of physical activity participation among New South Wales school students." Aust N Z J Public Health **26**(4): 371-4.

Boreham, C., P. J. Robson, et al. (2004). "Tracking of physical activity, fitness, body composition and diet from adolescence to young adulthood: The Young Hearts Project, Northern Ireland." Int J Behav Nutr Phys Act **1**(1): 14.

Boreham, C., J. Twisk, et al. (2002). "Associations between physical fitness and activity patterns during adolescence and cardiovascular risk factors in young adulthood: the Northern Ireland Young Hearts Project." Int J Sports Med **23 Suppl 1**: S22-6.

Boreham, C. A., V. J. Paliczka, et al. (1990). "A comparison of the PWC170 and 20-MST tests of aerobic fitness in adolescent schoolchildren." J Sports Med Phys Fitness **30**(1): 19-23.

Boreham, C. A., J. Twisk, et al. (1997). "Physical activity, sports participation, and risk factors in adolescents." Med Sci Sports Exerc **29**(6): 788-93.

Bouchard, C., F. T. Dionne, et al. (1992). "Genetics of aerobic and anaerobic performances." Exerc Sport Sci Rev **20**: 27-58.

Braddon, F. E., B. Rodgers, et al. (1986). "Onset of obesity in a 36 year birth cohort study." Br Med J (Clin Res Ed) **293**(6542): 299-303.

Brown, W. J., Y. D. Miller, et al. (2003). "Sitting time and work patterns as indicators of overweight and obesity in Australian adults." Int J Obes Relat Metab Disord **27**(11): 1340-6.

Brunner, E., M. J. Shipley, et al. (1999). "When does cardiovascular risk start? Past and present socioeconomic circumstances and risk factors in adulthood." J Epidemiol Community Health **53**(12): 757-64.

Cameron, A. J., T. A. Welborn, et al. (2003). "Overweight and obesity in Australia: the 1999-2000 Australian Diabetes, Obesity and Lifestyle Study (AusDiab)." Med J Aust **178**(9): 427-32.

Campbell, P. T., P. T. Katzmarzyk, et al. (2001). "Prediction of physical activity and physical work load capacity (PWC_{150}) in young adulthood from childhood and adolescence with consideration of parental measures." American Journal of Human Biology **13**: 190-196.

Campos, P., A. Saguy, et al. (2006). "The epidemiology of overweight and obesity: public health crisis or moral panic?" Int J Epidemiol **35**(1): 55-60.

Canada Fitness Survey (1983). Fitness and lifestyle in Canada. Ottawa, Canadian Fitness and Lifestyle Research Institute.

Caspersen, C. J., K. E. Powell, et al. (1985). "Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research." Public Health Rep **100**(2): 126-31.

Chan, C. B., E. Spangler, et al. (2003). "Cross-sectional relationship of pedometer-determined ambulatory activity to indicators of health." Obes Res **11**(12): 1563-70.

Chan, J. M., E. B. Rimm, et al. (1994). "Obesity, fat distribution, and weight gain as risk factors for clinical diabetes in men." Diabetes Care **17**(9): 961-9.

Ching, P. L., W. C. Willett, et al. (1996). "Activity level and risk of overweight in male health professionals." Am J Public Health **86**(1): 25-30.

Clarke, W. R. and R. M. Lauer (1993). "Does childhood obesity track into adulthood?" Crit Rev Food Sci Nutr **33**(4-5): 423-30.

Cleland, V., A. Venn, et al. (2005). "Parental exercise is associated with Australian children's extracurricular sports participation and cardiorespiratory fitness: a cross-sectional study." Int J Behav Nutr Phys Act **2**(3).

Coakley, E. H., E. B. Rimm, et al. (1998). "Predictors of weight change in men: results from the Health Professionals Follow-up Study." Int J Obes Relat Metab Disord **22**(2): 89-96.

Colditz, G. A. (1999). "Economic costs of obesity and inactivity." Med Sci Sports Exerc **31**(11 Suppl): S663-7.

Colditz, G. A., W. C. Willett, et al. (1995). "Weight gain as a risk factor for clinical diabetes mellitus in women." Ann Intern Med **122**(7): 481-6.

Cole, T. J., M. C. Bellizzi, et al. (2000). "Establishing a standard definition for child overweight and obesity worldwide: international survey." BMJ **320**(7244): 1240-3.

Cole, T. J. and M. F. Rolland-Cachera (2002). Measurement and definition. Child and Adolescent Obesity: Causes and Consequences, Prevention and Management. W. Burniat, T. J. Cole, I. Lissau and E. Poskitt. Cambridge, Cambridge University Press.

Cook, T., I. Rutishauser, et al. (2001). Comparable data on food and nutrient intake and physical measurements from the 1983, 1985 and 1995 national nutrition surveys. Canberra, Commonwealth Department of Health & Aged Care.

Coonan, W. E. and T. Dwyer (1983). Recommended Guidelines and Protocols for the Establishment of a National Fitness, Health and Physical Performance Survey in Australian Schools. Adelaide, Australian Council for Health, Physical Education and Recreation.

Cooper, A. R., A. Page, et al. (2000). "Physical activity patterns in normal, overweight and obese individuals using minute-by-minute accelerometry." Eur J Clin Nutr **54**(12): 887-94.

Craig, C. L., A. L. Marshall, et al. (2003). "International physical activity questionnaire: 12-country reliability and validity." Med Sci Sports Exerc **35**(8): 1381-95.

Craig, C. L., S. J. Russell, et al. (2004). "Twenty-year trends in physical activity among Canadian adults." Can J Public Health **95**(1): 59-63.

Crawford, D., R. W. Jeffery, et al. (2000). "Can anyone successfully control their weight? Findings of a three year community-based study of men and women." Int J Obes Relat Metab Disord **24**(9): 1107-10.

Crespo, C. J., E. Smit, et al. (2001). "Television watching, energy intake, and obesity in US children: results from the third National Health and Nutrition Examination Survey, 1988-1994." Arch Pediatr Adolesc Med **155**(3): 360-5.

Crouter, S. E., P. L. Schneider, et al. (2003). "Validity of 10 electronic pedometers for measuring steps, distance, and energy cost." Med Sci Sports Exerc **35**(8): 1455-60.

da Silva, R. B., L. Costa-Paiva, et al. (2005). "Association between habitual physical activity and parameters of physical fitness in postmenopausal women." Climacteric **8**(4): 360-70.

Daniels, S. R., P. R. Khoury, et al. (1997). "The utility of body mass index as a measure of body fatness in children and adolescents: differences by race and gender." Pediatrics **99**(6): 804-7.

Davey Smith, G., C. Hart, et al. (1997). "Lifetime socioeconomic position and mortality: prospective observational study." BMJ **314**(7080): 547-52.

Davison, K. K. and L. L. Birch (2004). "Lean and weight stable: behavioral predictors and psychological correlates." Obes Res **12**(7): 1085-93.

DeBusk, R. F., U. Stenestrand, et al. (1990). "Training effects of long versus short bouts of exercise in healthy subjects." Am J Cardiol **65**(15): 1010-3.

Deforche, B., J. Lefevre, et al. (2003). "Physical fitness and physical activity in obese and nonobese Flemish youth." Obes Res **11**(3): 434-41.

Department of Health (1996). Health Survey for England 1994, Joint Health Surveys Unit, National Centre for Social Research, Dept of Epidemiology & Public Health, Royal Free & University College Medical School. **2006**.

DeStefano, R. A., S. Caprio, et al. (2000). "Changes in body composition after a 12-wk aerobic exercise program in obese boys." Pediatr Diabetes **1**(2): 61-5.

DiPietro, L. (1995). "Physical activity, body weight, and adiposity: an epidemiological perspective." Exercise Sports Sci Rev **23**: 2475-303.

DiPietro, L., D. F. Williamson, et al. (1993). "The descriptive epidemiology of selected physical activities and body weight among adults trying to lose weight: the Behavioural Risk Factor Surveillance System Survey 1989." Int J Obes **17**: 69-76.

Dollman, J., K. Norton, et al. (2005). "Evidence for secular trends in children's physical activity behaviour." Br J Sports Med **39**(12): 892-7; discussion 897.

Dollman, J. and K. Ridley (2006). "Differences in body fatness, fat patterning and cardio-respiratory fitness between groups of Australian children formed on the basis of physical activity and television viewing guidelines." J Physical Activity & Health **1**: 1-14.

Dowda, M., B. E. Ainsworth, et al. (2001). "Environmental influences, physical activity, and weight status in 8- to 16-year-olds." Arch Pediatr Adolesc Med **155**(6): 711-7.

Droyvold, W. B., J. Holmen, et al. (2004). "Leisure time physical activity and change in body mass index: an 11-year follow-up study of 9357 normal weight healthy women 20-49 years old." Journal of Women's Health **13**(1): 55-62.

Droyvold, W. B., J. Holmen, et al. (2004). "BMI change and leisure time physical activity (LTPA): an 11-y follow-up study in apparently healthy men aged 20-69 y with normal weight at baseline." Int J Obes Relat Metab Disord **28**(3): 410-7.

Durnin, J. V. and M. M. Rahaman (1967). "The assessment of the amount of fat in the human body from measurement of skinfold thickness." Br J Nutr **21**: 681.

Dvorak, R. V., A. Tchernof, et al. (2000). "Respiratory fitness, free living physical activity, and cardiovascular disease risk in older individuals: a doubly labeled water study." J Clin Endocrinol Metab **85**(3): 957-63.

Dwyer, T., W. E. Coonan, et al. (1983). "An investigation of the effects of daily physical activity on the health of primary school students in South Australia." Int J Epidemiol **12**(3): 308-13.

Dwyer, T. and L. E. Gibbons (1994). "The Australian Schools Health and Fitness Survey: physical fitness related to blood pressure but not lipoproteins." Circulation **89**(4): 1539-44.

Eaton, C. B., K. L. Lapane, et al. (1995). "Physical activity, physical fitness, and coronary heart disease risk factors." Med Sci Sports Exerc **27**(3): 340-6.

Ebisu, T. (1985). "Splitting the distance of endurance running: on cardiovascular endurance and blood lipids." Jap J Phys Educ **30**(1): 37-43.

Eisenmann, J. C., R. T. Bartee, et al. (2002). "Physical activity, TV viewing, and weight in U.S. youth: 1999 Youth Risk Behavior Survey." Obes Res **10**(5): 379-85.

Ekelund, U., S. Brage, et al. (2005). "Physical activity energy expenditure predicts changes in body composition in middle-aged healthy whites: effect modification by age." Am J Clin Nutr **81**(5): 964-9.

Ekelund, U., E. Poortvliet, et al. (2001). "Physical activity in relation to aerobic fitness and body fat in 14- to 15-year-old boys and girls." Eur J Appl Physiol **85**(3-4): 195-201.

Elgar, F. J., C. Roberts, et al. (2005). "Sedentary behaviour, physical activity and weight problems in adolescents in Wales." Public Health **119**(6): 518-24.

Field, A. E., N. R. Cook, et al. (2005). "Weight status in childhood as a predictor of becoming overweight or hypertensive in early adulthood." Obes Res **13**(1): 163-9.

Figueroa-Colon, R., R. B. Arani, et al. (2000). "Paternal body fat is a longitudinal predictor of changes in body fat in premenarcheal girls." Am J Clin Nutr **71**(3): 829-34.

Flegal, K. M., M. D. Carroll, et al. (2002). "Prevalence and trends in obesity among US adults, 1999-2000." JAMA **288**(14): 1723-7.

Fogelholm, M. and K. Kukkonen-Harjula (2000). "Does physical activity prevent weight gain–a systematic review." Obes Rev **1**(2): 95-111.

Folsom, A. R., C. J. Caspersen, et al. (1985). "Leisure time physical activity and its relationship to coronary risk factors in a population-based sample. The Minnesota Heart Survey." Am J Epidemiol **121**(4): 570-9.

Freedman, D. S., L. K. Khan, et al. (2005). "Racial differences in the tracking of childhood BMI to adulthood." Obes Res **13**(5): 928-35.

Freedman, D. S., L. K. Khan, et al. (2005). "The relation of childhood BMI to adult adiposity: the Bogalusa Heart Study." Pediatrics **115**(1): 22-7.

Freedson, P. S. and K. Miller (2000). "Objective monitoring of physical activity using motion sensors and heart rate." Res Q Exerc Sport **71**(2 Suppl): S21-9.

French, S. A., R. W. Jeffery, et al. (1994). "Predictors of weight change over two years among a population of working adults: the Healthy Worker Project." Int J Obes Relat Metab Disord **18**(3): 145-54.

Garabrant, D. H., J. M. Peters, et al. (1984). "Job activity and colon cancer risk." Am J Epidemiol **119**(6): 1005-14.

Gerhardsson, M., S. E. Norell, et al. (1986). "Sedentary jobs and colon cancer." Am J Epidemiol **123**(5): 775-80.

Glenmark, B., G. Hedberg, et al. (1994). "Prediction of physical activity level in adulthood by physical characteristics, physical performance and physical activity in adolescence: an 11-year follow-up study." Eur J Appl Physiol Occup Physiol **69**(6): 530-8.

Goran, M. I., R. Shewchuk, et al. (1998). "Longitudinal changes in fatness in white children: no effect of childhood energy expenditure." Am J Clin Nutr **67**(2): 309-16.

Gordon-Larsen, P., L. S. Adair, et al. (2002). "Ethnic differences in physical activity and inactivity patterns and overweight status." Obes Res **10**(3): 141-9.

Gortmaker, S. L., A. Must, et al. (1996). "Television viewing as a cause of increasing obesity among children in the United States, 1986-1990." Arch Pediatr Adolesc Med **150**(4): 356-62.

Gregg, E. W., J. A. Cauley, et al. (2003). "Relationship of changes in physical activity and mortality among older women." JAMA **289**(18): 2379-86.

Gretebeck, R. J. and H. J. Montoye (1992). "Variability of some objective measures of physical activity." Med Sci Sports Exerc **24**(10): 1167-72.

Grund, A., H. Vollbrecht, et al. (2000). "No effect of gender on different components of daily energy expenditure in free living prepubertal children." Int J Obes Relat Metab Disord **24**(3): 299-305.

Guillaume, M., L. Lapidus, et al. (1997). "Physical activity, obesity, and cardiovascular risk factors in children. The Belgian Luxembourg Child Study II." Obes Res **5**(6): 549-56.

Guo, S. S., A. F. Roche, et al. (1994). "The predictive value of childhood body mass index values for overweight at age 35 y." Am J Clin Nutr **59**(4): 810-9.

Gutierrez-Fisac, J. L., P. Guallar-Castillon, et al. (2002). "Work-related physical activity is not associated with body mass index and obesity." Obes Res **10**(4): 270-6.

Gutin, B. and S. Owens (1999). "Role of exercise intervention in improving body fat distribution and risk profile in children." Am J Human Biol **11**(2): 237-247.

Haapanen, N., S. Miilunpalo, et al. (1997). "Association between leisure time physical activity and 10-year body mass change among working-aged men and women." Int J Obes Relat Metab Disord **21**(4): 288-96.

Hands, B., H. Parker, et al. (2004). Physical activity and nutrition levels in West Australian children and adolescents: Report. Perth, Western Australian Government.

Harnack, L. J., R. W. Jeffery, et al. (2000). "Temporal trends in energy intake in the United States: an ecologic perspective." Am J Clin Nutr **71**(6): 1478-84.

Hasselstrom, H., S. E. Hansen, et al. (2002). "Physical fitness and physical activity during adolescence as predictors of cardiovascular disease risk in young adulthood. Danish Youth and Sports Study. An eight-year follow-up study." Int J Sports Med **23 Suppl 1**: S27-31.

Heini, A. F. and R. L. Weinsier (1997). "Divergent trends in obesity and fat intake patterns: the American paradox." Am J Med **102**(3): 259-64.

Helmrich, S. P., D. R. Ragland, et al. (1991). "Physical activity and reduced occurrence of non-insulin-dependent diabetes mellitus." N Engl J Med **325**(3): 147-52.

Hill, J. O., H. R. Wyatt, et al. (2003). "Obesity and the environment: where do we go from here?" Science **299**(5608): 853-5.

Hornbuckle, L. M., D. R. Bassett, Jr., et al. (2005). "Pedometer-determined walking and body composition variables in african-american women." Med Sci Sports Exerc **37**(6): 1069-74.

Hu, F. B., M. F. Leitzmann, et al. (2001). "Physical activity and television watching in relation to risk for type 2 diabetes mellitus in men." Arch Intern Med **161**(12): 1542-8.

Hu, F. B., T. Y. Li, et al. (2003). "Television watching and other sedentary behaviors in relation to risk of obesity and type 2 diabetes mellitus in women." JAMA **289**(14): 1785-91.

Hu, G., H. Pekkarinen, et al. (2002). "Commuting, leisure-time physical activity, and cardiovascular risk factors in China." Med Sci Sports Exerc **34**(2): 234-8.

Huang, Z., W. C. Willett, et al. (1998). "Body weight, weight change, and risk for hypertension in women." Ann Intern Med **128**(2): 81-8.

IARC (2002). IARC Handbooks of Cancer Prevention, Vol 6. Weight control and physical activity. Lyon, International Agency for Research on Cancer.

Jakicic, J. M., B. H. Marcus, et al. (2003). "Effect of exercise duration and intensity on weight loss in overweight, sedentary women: a randomized trial." JAMA **290**(10): 1323-30.

Janssen, I., P. T. Katzmarzyk, et al. (2004). "Overweight and obesity in Canadian adolescents and their associations with dietary habits and physical activity patterns." J Adolesc Health **35**(5): 360-7.

Janssen, I., P. T. Katzmarzyk, et al. (2005). "Comparison of overweight and obesity prevalence in school-aged youth from 34 countries and their relationships with physical activity and dietary patterns." Obes Rev **6**(2): 123-32.

Jeffery, R. W., A. Drewnowski, et al. (2000). "Long-term maintenance of weight loss: current status." Health Psychol **19**(1 Suppl): 5-16.

Jeffery, R. W., M. T. McGuire, et al. (2002). "Prevalence and correlates of large weight gains and losses." Int J Obes Relat Metab Disord **26**(7): 969-72.

Johnson, M. S., R. Figueroa-Colon, et al. (2000). "Aerobic fitness, not energy expenditure, influences subsequent increase in adiposity in black and white children." Pediatrics **106**(4): E50.

Kahn, H. S., L. M. Tatham, et al. (1997). "Stable behaviors associated with adults' 10-year change in body mass index and likelihood of gain at the waist." Am J Public Health **87**(5): 747-54.

Kampert, J. B., S. N. Blair, et al. (1996). "Physical activity, physical fitness, and all-cause and cancer mortality: a prospective study of men and women." Ann Epidemiol **6**(5): 452-7.

Kannel, W. B., A. Belanger, et al. (1986). "Physical activity and physical demand on the job and risk of cardiovascular disease and death: the Framingham Study." Am Heart J **112**(4): 820-5.

Kaplan, G. A., W. J. Strawbridge, et al. (1996). "Natural history of leisure-time physical activity and its correlates: associations with mortality from all causes and cardiovascular disease over 28 years." Am J Epidemiol **144**(8): 793-7.

Kaplan, G. A., G. Turrell, et al. (2001). "Childhood socioeconomic position and cognitive function in adulthood." Int J Epidemiol **30**(2): 256-63.

Kaur, H., W. S. Choi, et al. (2003). "Duration of television watching is associated with increased body mass index." J Pediatr **143**(4): 506-11.

Kemper, H. C., G. B. Post, et al. (1999). "Lifestyle and obesity in adolescence and young adulthood: results from the Amsterdam Growth And Health Longitudinal Study (AGAHLS)." Int J Obes Relat Metab Disord **23 Suppl 3**: S34-40.

Kemper, H. C. G. and W. van Mechelen (1995). Physical fitness and the relationship to physical activity. The Amsterdam Growth Study: A Longitudinal Analysis of Health, Fitness and Lifestyle. H. C. G. Kemper. Amsterdam, Human Kinetics: 174-188.

Kettaneh, A., J. M. Oppert, et al. (2005). "Changes in physical activity explain paradoxical relationship between baseline physical activity and adiposity changes in adolescent girls: the FLVS II study." Int J Obes (Lond) **29**(6): 586-93.

Kim, J., A. Must, et al. (2005). "Relationship of physical fitness to prevalence and incidence of overweight among schoolchildren." Obes Res **13**(7): 1246-54.

Kimm, S. Y., B. A. Barton, et al. (2001). "Racial divergence in adiposity during adolescence: The NHLBI Growth and Health Study." Pediatrics **107**(3): E34.

Kimm, S. Y., N. W. Glynn, et al. (2002). "Decline in physical activity in black girls and white girls during adolescence." N Engl J Med **347**(10): 709-15.

Kimm, S. Y., N. W. Glynn, et al. (2005). "Relation between the changes in physical activity and body-mass index during adolescence: a multicentre longitudinal study." Lancet **366**(9482): 301-7.

King, G. A., E. C. Fitzhugh, et al. (2001). "Relationship of leisure-time physical activity and occupational activity to the prevalence of obesity." Int J Obes Relat Metab Disord **25**(5): 606-12.

Klesges, R. C., L. M. Klesges, et al. (1992). "A longitudinal analysis of the impact of dietary intake and physical activity on weight change in adults." Am J Clin Nutr **55**(4): 818-22.

Knittle, J. L., K. Timmers, et al. (1979). "The growth of adipose tissue in children and adolescents. Cross sectional and longitudinal studies of adipose cell number and size." J Clin Investigation **63**: 239-46.

Koh-Banerjee, P., N. F. Chu, et al. (2003). "Prospective study of the association of changes in dietary intake, physical activity, alcohol consumption, and smoking with 9-y gain in waist circumference among 16 587 US men." Am J Clin Nutr **78**(4): 719-27.

Kohl, H. W., S. N. Blair, et al. (1988). "A mail survey of physical activity habits as related to measured physical fitness." Am J Epidemiol **127**(6): 1228-39.

Kronenberg, F., M. A. Pereira, et al. (2000). "Influence of leisure time physical activity and television watching on atherosclerosis risk factors in the NHLBI Family Heart Study." Atherosclerosis **153**(2): 433-43.

Kuh, D., R. Hardy, et al. (2002). "Mortality in adults aged 26-54 years related to socioeconomic conditions in childhood and adulthood: post war birth cohort study." BMJ **325**(7372): 1076-80.

Kuh, D. J. and C. Cooper (1992). "Physical activity at 36 years: patterns and childhood predictors in a longitudinal study." J Epidemiol Community Health **46**(2): 114-9.

Kvaavik, E., G. S. Tell, et al. (2003). "Predictors and tracking of body mass index from adolescence into adulthood: follow-up of 18 to 20 years in the Oslo Youth Study." Arch Pediatr Adolesc Med **157**(12): 1212-8.

Lahti-Koski, M., P. Pietinen, et al. (2002). "Associations of body mass index and obesity with physical activity, food choices, alcohol intake, and smoking in the 1982-1997 FINRISK Studies." Am J Clin Nutr **75**(5): 809-17.

Laitinen, J., C. Power, et al. (2001). "Family social class, maternal body mass index, childhood body mass index, and age at menarche as predictors of adult obesity." Am J Clin Nutr **74**(3): 287-94.

Landis, J. R. and G. G. Koch (1977). "The measurement of observer agreement for categorical data." Biometrics **33**: 159-74.

Lauer, R. M. and W. R. Clarke (1989). "Childhood risk factors for high adult blood pressure: the Muscatine Study." Pediatrics **84**(4): 633-41.

Le Masurier, G. C. and C. Tudor-Locke (2003). "Comparison of pedometer and accelerometer accuracy under controlled conditions." Med Sci Sports Exerc **35**(5): 867-71.

Lee, I. M. (2003). "Physical activity and cancer prevention--data from epidemiologic studies." Med Sci Sports Exerc **35**(11): 1823-7.

Lee, I. M., C. C. Hsieh, et al. (1995). "Exercise intensity and longevity in men. The Harvard Alumni Health Study." JAMA **273**(15): 1179-84.

Lee, I. M., R. S. Paffenbarger, Jr., et al. (1991). "Physical activity and risk of developing colorectal cancer among college alumni." J Natl Cancer Inst **83**(18): 1324-9.

Lefevre, J., R. Philippaerts, et al. (2002). "Relation between cardiovascular risk factors at adult age, and physical activity during youth and adulthood: the Leuven Longitudinal Study on Lifestyle, Fitness and Health." Int J Sports Med **23 Suppl 1**: S32-8.

Leon, A. S. and J. Connett (1991). "Physical activity and 10.5 year mortality in the Multiple Risk Factor Intervention Trial (MRFIT)." Int J Epidemiol **20**(3): 690-7.

Leon, A. S., M. J. Myers, et al. (1997). "Leisure time physical activity and the 16-year risks of mortality from coronary heart disease and all-causes in the Multiple Risk Factor Intervention Trial (MRFIT)." Int J Sports Med **18 Suppl 3**: S208-15.

Levin, S., R. Lowry, et al. (2003). "Physical activity and body mass index among US adolescents: youth risk behavior survey, 1999." Arch Pediatr Adolesc Med **157**(8): 816-20.

Levine, J., L. M. Lanningham-Foster, et al. (2005). "Interindividual variation in posture allocation: possible role in human obesity." Science **307**: 584-6.

Liebman, M., S. Pelican, et al. (2003). "Dietary intake, eating behavior, and physical activity-related determinants of high body mass index in rural communities in Wyoming, Montana, and Idaho." Int J Obes Relat Metab Disord **27**(6): 684-92.

Lissner, L. and B. L. Heitmann (1995). "Dietary fat and obesity: evidence from epidemiology." Eur J Clin Nutr **49**(2): 79-90.

Lochen, M. L. and K. Rasmussen (1992). "The Tromso study: physical fitness, self reported physical activity, and their relationship to other coronary risk factors." J Epidemiol Community Health **46**(2): 103-7.

Lynch, J. (2000). Historical socioeconomic status questionnaire, (unpublished work).

Lynch, J. W., G. A. Kaplan, et al. (1994). "Childhood and adult socioeconomic status as predictors of mortality in Finland." Lancet **343**(8896): 524-7.

Macera, C. A. and M. Pratt (2000). "Public health surveillance of physical activity." Res Q Exerc Sport **71**(2 Suppl): S97-103.

Maes, H. H., M. C. Neale, et al. (1997). "Genetic and environmental factors in relative body weight and human adiposity." Behav Genet **27**(4): 325-51.

Maffeis, C., G. Talamini, et al. (1998). "Influence of diet, physical activity and parents' obesity on children's adiposity: a four-year longitudinal study." Int J Obes Relat Metab Disord **22**(8): 758-64.

Magarey, A. M., L. A. Daniels, et al. (2001). "Prevalence of overweight and obesity in Australian children and adolescents: reassessment of 1985 and 1995 data against new standard international definitions." Med J Aust **174**(11): 561-4.

Magarey, A. M., L. A. Daniels, et al. (2003). "Predicting obesity in early adulthood from childhood and parental obesity." Int J Obes Relat Metab Disord **27**(4): 505-13.

Magliano, D., D. Liew, et al. (2003). "Accuracy of the Australian National Death Index: comparison with adjudicated fatal outcomes among Australian participants in the Long-term Intervention with Pravastatin in Ischaemic Disease (LIPID) study." Aust N Z J Public Health **27**(6): 649-53.

Malina, R. M. (1996). "Tracking of physical activity and physical fitness across the lifespan." Res Q Exerc Sport **67**(3 Suppl): S48-57.

Malina, R. M. (2001). "Physical activity and fitness: pathways from childhood to adulthood." American Journal of Human Biology **13**: 162-172.

Malina, R. M., G. P. Beunen, et al. (1995). "Fatness and physical fitness of girls 7 to 17 years." Obes Res **3**(3): 221-31.

Manson, J. E., D. M. Nathan, et al. (1992). "A prospective study of exercise and incidence of diabetes among US male physicians." JAMA **268**(1): 63-7.

Manson, J. E., E. B. Rimm, et al. (1991). "Physical activity and incidence of non-insulin-dependent diabetes mellitus in women." Lancet **338**(8770): 774-8.

Manson, J. E., W. C. Willett, et al. (1995). "Body weight and mortality among women." N Engl J Med **333**(11): 677-85.

Marshall, A. and A. Bauman (2001). The International Physical Activity Questionnaire: Summary Report of the Reliablity and Validity Studies, IPAQ Executive Committee.

Martinez, M. E., E. Giovannucci, et al. (1997). "Leisure-time physical activity, body size, and colon cancer in women. Nurses' Health Study Research Group." J Natl Cancer Inst **89**(13): 948-55.

McCarthy, H. D., S. M. Ellis, et al. (2003). "Central overweight and obesity in British youth aged 11-16 years: cross sectional surveys of waist circumference." BMJ **326**(7390): 624.

McCarthy, S. N., M. J. Gibney, et al. (2002). "Overweight, obesity and physical activity levels in Irish adults: evidence from the North/South Ireland food consumption survey." Proc Nutr Soc **61**(1): 3-7.

McLennan, W. (1998). 1996 Census of population and housing: socioeconomic index for areas. Canberra, Australian Bureau of Statistics.

McMurray, R. G., B. E. Ainsworth, et al. (1998). "Is physical activity or aerobic power more influential on reducing cardiovascular disease risk factors?" Med Sci Sports Exerc **30**(10): 1521-9.

McMurray, R. G., J. S. Harrell, et al. (2002). "A school-based intervention can reduce body fat and blood pressure in young adolescents." J Adolesc Health **31**(2): 125-32.

McMurray, R. G., J. S. Harrell, et al. (2000). "The influence of physical activity, socioeconomic status, and ethnicity on the weight status of adolescents." Obes Res **8**(2): 130-9.

Mensink, G. B., D. W. Heerstrass, et al. (1997). "Intensity, duration, and frequency of physical activity and coronary risk factors." Med Sci Sports Exerc **29**(9): 1192-8.

Miller, R., W. Brown, et al. (2006). "But what about swimming and cycling? How to "count" non-ambulatory activity when using pedometers to assess physical activity." Journal of Physical Activity and Health **3**: 257-266.

Mishra, G., K. Ball, et al. (2001). "The measurement of socio-economic status: investigation of gender- and age-specific indicators in Australia: National Health Survey 1995." Social Indicators Research **56**: 73-89.

Molnar, D. and B. Livingstone (2000). "Physical activity in relation to overweight and obesity in children and adolescents." Eur J Pediatr **159 Suppl 1**: S45-55.

Montoye, H. J., H. C. G. Kemper, et al. (1996). Measuring physical activity and energy expenditure. Champaign, Human Kinetics.

Moore, L. L., D. Gao, et al. (2003). "Does early physical activity predict body fat change throughout childhood?" Prev Med **37**(1): 10-7.

Morrow, J. R. and P. Freedson (1994). "Relationship between habitual physical activity and aerobic fitness in adolescents." Ped Exerc Sci **6**: 315-329.

Mo-suwan, L., S. Pongprapai, et al. (1998). "Effects of a controlled trial of a school-based exercise program on the obesity indexes of preschool children." Am J Clin Nutr **68**(5): 1006-11.

Mota, J., P. Santos, et al. (2002). "Differences of daily physical activity levels of children according to body mass index." Ped Exerc Sci **14**: 442-52.

Mummery, W. K., G. M. Schofield, et al. (2005). "Occupational sitting time and overweight and obesity in Australian workers." Am J Prev Med **29**(2): 91-7.

Murgatroyd, P. R., P. S. Shetty, et al. (1993). "Techniques for the measurement of human energy expenditure: a practical guide." Int J Obes **17**: 549-68.

Must, A., P. F. Jacques, et al. (1992). "Long-term morbidity and mortality of overweight adolescents. A follow-up of the Harvard Growth Study of 1922 to 1935." N Engl J Med **327**(19): 1350-5.

Must, A. and D. J. Tybor (2005). "Physical activity and sedentary behavior: a review of longitudinal studies of weight and adiposity in youth." Int J Obes (Lond) **29 Suppl 2**: S84-96.

Nassis, G. P., G. Psarra, et al. (2005). "Central and total adiposity are lower in overweight and obese children with high cardiorespiratory fitness." Eur J Clin Nutr **59**(1): 137-41.

National Health and Medical Research Council (2003). Clinical Practice Guidelines for Management of Overweight and Obesity in Adults. Canberra, National Health and Medical Research Council.

National Health and Medical Research Council (2003). Clinical Practice Guidelines for the Management of Overweight and Obesity in Children and Adolescents. Canberra, National Health and Medical Research Council.

National Institutes of Health (1998). "Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults--The Evidence Report. National Institutes of Health." Obes Res **6 Suppl 2**: 51S-209S.

Neumark-Sztainer, D., M. Wall, et al. (2006). "Obesity, disordered eating, and eating disorders in a longitudinal study of adolescents: how do dieters fare 5 years later?" J Am Diet Assoc **106**(4): 559-68.

NIH (1996). "Physical activity and cardiovascular health. NIH Consensus Development Panel on Physical Activity and Cardiovascular Health." JAMA **276**(3): 241-6.

O'Dea, J. A. (2005). "Prevention of child obesity: 'first, do no harm'." Health Educ Res **20**(2): 259-65.

Ogden, C. L., K. M. Flegal, et al. (2002). "Prevalence and trends in overweight among US children and adolescents, 1999-2000." JAMA **288**(14): 1728-32.

Olds, T. S. (2006). "Obesity Wars." Sport Health **24**(4): 6-10.

O'Loughlin, J., K. Gray-Donald, et al. (2000). "One- and two-year predictors of excess weight gain among elementary schoolchildren in multiethnic, low-income, inner-city neighborhoods." Am J Epidemiol **152**(8): 739-46.

Paeratakul, S., B. M. Popkin, et al. (1998). "Changes in diet and physical activity affect the body mass index of Chinese adults." Int J Obes Relat Metab Disord **22**(5): 424-31.

Paffenbarger, R. S., Jr., R. T. Hyde, et al. (1986). "Physical activity, other life-style patterns, cardiovascular disease and longevity." Acta Med Scand Suppl **711**: 85-91.

Paffenbarger, R. S., Jr., R. T. Hyde, et al. (1986). "Physical activity, all-cause mortality, and longevity of college alumni." N Engl J Med **314**(10): 605-13.

Page, A., A. R. Cooper, et al. (2005). "Physical activity patterns in nonobese and obese children assessed using minute-by-minute accelerometry." Int J Obes (Lond) **29**(9): 1070-6.

Pangrazi, R. P., A. Beighle, et al. (2003). "Impact of Promoting Lifestyle Activity for Youth (PLAY) on children's physical activity." J Sch Health **73**(8): 317-21.

Parsons, T. J., O. Manor, et al. (2006). "Physical activity and change in body mass index from adolescence to mid-adulthood in the 1958 British cohort." Int J Epidemiol **35**(1): 197-204.

Parsons, T. J., C. Power, et al. (1999). "Childhood predictors of adult obesity: a systematic review." Int J Obes Relat Metab Disord **23 Suppl 8**: S1-107.

Pate, R., B. J. Long, et al. (1994). "Descriptive epidemiology of physical activity in adolescents." Ped Exerc Sci **6**: 434-47.

Pate, R. R., M. Pratt, et al. (1995). "Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine." JAMA **273**(5): 402-7.

Pereira, M. A., S. J. FitzerGerald, et al. (1997). "A collection of Physical Activity Questionnaires for health-related research." Med Sci Sports Exerc **29**(6 Suppl): S1-205.

Petersen, L., P. Schnohr, et al. (2004). "Longitudinal study of the long-term relation between physical activity and obesity in adults." Int J Obes Relat Metab Disord **28**(1): 105-12.

Petzl, D. H., P. Haber, et al. (1988). "Reliability of estimation of maximum performance capacity on the basis of submaximum ergometric stress tests in children 10-14 years old." Eur J Pediatr **147**: 174-178.

Pietrobelli, A., M. S. Faith, et al. (1998). "Body mass index as a measure of adiposity among children and adolescents: a validation study." J Pediatr **132**(2): 204-10.

Pols, M. A., P. H. Peeters, et al. (1998). "Methodological aspects of physical activity assessment in epidemiological studies." Eur J Epidemiol **14**(1): 63-70.

Power, C., J. K. Lake, et al. (1997). "Body mass index and height from childhood to adulthood in the 1958 British born cohort." Am J Clin Nutr **66**(5): 1094-101.

Powers, J., J. Ball, et al. (2000). "Effectiveness of the National Death Index for establishing the vital status of older women in the Australian Longitudinal Study on Women's Health." Aust N Z J Public Health **24**(5): 526-8.

Pratt, M., C. A. Macera, et al. (1999). "Levels of physical activity and inactivity in children and adults in the United States: current evidence and research issues." Med Sci Sports Exerc **31**(11 Suppl): S526-33.

Prentice, A. M. and S. A. Jebb (1995). "Obesity in Britain: gluttony or sloth?" BMJ **311**(7002): 437-9.

Prentice, A. M. e. (1990). The doubly-labelled water method for measuring energy expenditure: Technical recommendations for use in humans. A consensus report by the International Dietary Energy Consultancy Working Group. Vienna, International Atomic Energy Agency.

Psarra, G., G. P. Nassis, et al. (2005). "Short-term predictors of abdominal obesity in children." Eur J Public Health.

Pyke, J. E. (1985). Australian Health and Fitness Survey 1985. South Australia, The Australian Council for Health, Physical Education and Recreation.

Raitakari, O. T., S. Taimela, et al. (1997). "Associations between physical activity and risk factors for coronary heart disease: the Cardiovascular Risk in Young Finns Study." Med Sci Sports Exerc **29**(8): 1055-61.

Raustorp, A., R. P. Pangrazi, et al. (2004). "Physical activity level and body mass index among schoolchildren in south-eastern Sweden." Acta Paediatr **93**(3): 400-4.

Rennie, K. L., M. B. Livingstone, et al. (2005). "Association of physical activity with body-composition indexes in children aged 6-8 y at varied risk of obesity." Am J Clin Nutr **82**(1): 13-20.

Rexrode, K. M., V. J. Carey, et al. (1998). "Abdominal adiposity and coronary heart disease in women." Jama **280**(21): 1843-8.

Rexrode, K. M., C. H. Hennekens, et al. (1997). "A prospective study of body mass index, weight change, and risk of stroke in women." JAMA **277**(19): 1539-45.

Rimm, E. B., M. J. Stampfer, et al. (1995). "Body size and fat distribution as predictors of coronary heart disease among middle-aged and older US men." Am J Epidemiol **141**(12): 1117-27.

Rissanen, A. M., M. Heliovaara, et al. (1991). "Determinants of weight gain and overweight in adult Finns." Eur J Clin Nutr **45**(9): 419-30.

Robinson, T. N., L. D. Hammer, et al. (1993). "Does television viewing increase obesity and reduce physical activity? Cross-sectional and longitudinal analyses among adolescent girls." Pediatrics **91**(2): 273-80.

Rockhill, B., W. C. Willett, et al. (1999). "A prospective study of recreational physical activity and breast cancer risk." Arch Intern Med **159**(19): 2290-6.

Rolland-Cachera, M. F., M. Deheeger, et al. (1996). "Nutritional changes between 1978 and 1995 in 10 year olds in French children." Int J Obes **20**(Suppl. 4): Abstr.105, 53.

Ross, R., D. Dagnone, et al. (2000). "Reduction in obesity and related comorbid conditions after diet-induced weight loss or exercise-induced weight loss in men. A randomized, controlled trial." Ann Intern Med **133**(2): 92-103.

Ross, R., I. Janssen, et al. (2004). "Exercise-induced reduction in obesity and insulin resistance in women: a randomized controlled trial." Obes Res **12**(5): 789-98.

Rothman, K. J. (2002). Epidemiology. An Introduction. New York, Oxford University Press.

Rowlands, A. V., R. G. Eston, et al. (1997). "Measurement of physical activity in children with particular reference to the use of heart rate and pedometry." Sports Med **24**(4): 258-72.

Rowlands, A. V., R. G. Eston, et al. (1999). "Relationship between activity levels, aerobic fitness, and body fat in 8- to 10-yr-old children." J Appl Physiol **86**(4): 1428-35.

Rowlands, A. V., D. K. Ingledew, et al. (2000). "The effect of type of physical activity measure on the relationship between body fatness and habitual physical activity in children: a meta-analysis." Ann Hum Biol **27**(5): 479-97.

Rush, E. C., L. D. Plank, et al. (2003). "Body composition and physical activity in New Zealand Maori, Pacific and European children aged 5-14 years." Br J Nutr **90**(6): 1133-9.

Rzewnicki, R., Y. Vanden Auweele, et al. (2003). "Addressing overreporting on the International Physical Activity Questionnaire (IPAQ) telephone survey with a population sample." Public Health Nutr **6**(3): 299-305.

Sallis, J., T. L. McKenzie, et al. (1993). "Project SPARK: effects of physical education on adiposity in children." Ann N Y Acad Sci **29**(699): 127-36.

Sallis, J. and K. Patrick (1994). "Physical activity guidelines for adolescents: consensus statement." Ped Exerc Sci **6**: 302-14.

Sallis, J. F., M. J. Buono, et al. (1993). "Seven-day recall and other physical activity self-reports in children and adolescents." Med Sci Sports Exerc **25**(1): 99-108.

Sallis, J. F., W. L. Haskell, et al. (1986). "Moderate-intensity physical activity and cardiovascular risk factors: the Stanford Five-City Project." Prev Med **15**(6): 561-8.

Sallis, J. F., J. J. Prochaska, et al. (2000). "A review of correlates of physical activity of children and adolescents." Med Sci Sports Exerc **32**(5): 963-75.

Sallis, J. F. and B. E. Saelens (2000). "Assessment of physical activity by self-report: status, limitations, and future directions." Res Q Exerc Sport **71**(2 Suppl): S1-14.

Salmon, J., A. Bauman, et al. (2000). "The association between television viewing and overweight among Australian adults participating in varying levels of leisure-time physical activity." Int J Obes Relat Metab Disord **24**(5): 600-6.

Salmon, J., N. Owen, et al. (2003). "Physical activity and sedentary behavior: a population-based study of barriers, enjoyment, and preference." Health Psychol **22**(2): 178-88.

Salmon, J., A. Telford, et al. (2004). The Children's Leisure Activities Study (CLASS) Summary Report. Melbourne, Deakin University.

Salmon, J., A. Timperio, et al. (2005). "Trends in children's active commuting, school sport & physical education in high & low socioeconomic status areas of Melbourne, Victoria, 1985-2001." Aust N Z J Public Health **29**(4): 337-342.

Schlicker, S. A., S. T. Borra, et al. (1994). "The weight and fitness status of United States children." Nutr Rev **52**(1): 11-7.

Schmidt, G. J., D. J. Stensel, et al. (1997). "Blood pressure, lipids, lipoproteins, body fat and physical activity of Singapore children." J Paediatr Child Health **33**(6): 484-90.

Schmidt, G. J., J. J. Walkuski, et al. (1998). "The Singapore Youth Coronary Risk and Physical Activity Study." Med Sci Sports Exerc **30**(1): 105-13.

Schmidt, M., C. L. Blizzard, et al. (In Press). "Practical considerations when using pedometers to assess physical activity in population studies." Res Q Exerc Sport.

Schmidt, M. D., P. S. Freedson, et al. (2003). "Estimating physical activity using the CSA accelerometer and a physical activity log." Med Sci Sports Exerc **35**(9): 1605-11.

Schmitz, K. H., D. R. Jacobs, Jr., et al. (2000). "Physical activity and body weight: associations over ten years in the CARDIA study. Coronary Artery Risk Development in Young Adults." Int J Obes Relat Metab Disord **24**(11): 1475-87.

Schneider, P. L., S. E. Crouter, et al. (2004). "Pedometer measures of free-living physical activity: comparison of 13 models." Med Sci Sports Exerc **36**(2): 331-5.

Schneider, P. L., S. E. Crouter, et al. (2003). "Accuracy and reliability of 10 pedometers for measuring steps over a 400-m walk." Med Sci Sports Exerc **35**(10): 1779-84.

Schonhofer, B., P. Ardes, et al. (1997). "Evaluation of a movement detector to measure daily activity in patients with chronic lung disease." Eur Respir J **10**(12): 2814-9.

Seidell, J. C. (1997). "Time trends in obesity: an epidemiological perspective." Horm Metab Res **29**(4): 155-8.

Seidell, J. C. (2005). The epidemiology of obesity: a global perspective. Obesity Prevention and Public Health. D. Crawford and R. W. Jeffery. New York, Oxford University Press: 3-19.

Sequeira, M. M., M. Rickenbach, et al. (1995). "Physical activity assessment using a pedometer and its comparison with a questionnaire in a large population survey." Am J Epidemiol **142**(9): 989-99.

Serdula, M. K., D. Ivery, et al. (1993). "Do obese children become obese adults? A review of the literature." Prev Med **22**(2): 167-77.

Shaper, A. G., G. Wannamethee, et al. (1991). "Physical activity and ischaemic heart disease in middle-aged British men." Br Heart J **66**(5): 384-94.

Sherwood, N. E., R. W. Jeffery, et al. (2000). "Predictors of weight gain in the Pound of Prevention study." Int J Obes Relat Metab Disord **24**(4): 395-403.

Sieminski, D. J., L. L. Cowell, et al. (1997). "Physical activity monitoring in patients with peripheral arterial occlusive disease." J Cardiopulm Rehabil **17**(1): 43-7.

Sinaiko, A. R., R. P. Donahue, et al. (1999). "Relation of weight and rate of increase in weight during childhood and adolescence to body size, blood pressure, fasting insulin, and lipids in young adults. The Minneapolis Children's Blood Pressure Study." Circulation **99**(11): 1471-6.

Sirard, J. R. and R. R. Pate (2001). "Physical activity assessment in children and adolescents." Sports Med **31**(6): 439-54.

Slattery, M. L., A. McDonald, et al. (1992). "Associations of body fat and its distribution with dietary intake, physical activity, alcohol, and smoking in blacks and whites." Am J Clin Nutr **55**(5): 943-9.

Slentz, C. A., B. D. Duscha, et al. (2004). "Effects of the amount of exercise on body weight, body composition, and measures of central obesity: STRRIDE--a randomized controlled study." Arch Intern Med **164**(1): 31-9.

Sobal, J. and A. J. Stunkard (1989). "Socioeconomic status and obesity: a review of the literature." Psychol Bull **105**(2): 260-75.

Social Science Data Archives (1998). Census of Population and Housing, 1986: Socio-Economic Status Indicator File. User's Guide for the Machine-Readable Data File (SSDA Census Series). Canberra, Social Science Data Archives.

Speakman, J. R. and C. Selman (2003). "Physical activity and resting metabolic rate." Proc Nutr Soc **62**(3): 621-34.

Srinivasan, S. R., W. Bao, et al. (1996). "Adolescent overweight is associated with adult overweight and related multiple cardiovascular risk factors: the Bogalusa Heart Study." Metabolism **45**(2): 235-40.

St Jeor, S. T., R. L. Brunner, et al. (1995). "Who are the weight maintainers?" Obes Res **3 Suppl 2**: 249s-259s.

St Jeor, S. T., R. L. Brunner, et al. (1997). "A classification system to evaluate weight maintainers, gainers, and losers." J Am Diet Assoc **97**(5): 481-8.

Stephenson, J., A. Bauman, et al. (2000). The costs of illness attributable to physical inactivity. Canberra, Commonwealth Department of Health and Aged Care.

Strauss, R. S. (2000). "Childhood obesity and self-esteem." Pediatrics **105**(1): e15.

Summerbell, C. D., E. Waters, et al. (2005). "Interventions for preventing obesity in children." Cochrane Database Syst Rev(3): CD001871.

Suzuki, I., H. Yamada, et al. (1998). "Cardiovascular fitness, physical activity and selected coronary heart disease risk factors in adults." J Sports Med Phys Fitness **38**(2): 149-57.

Tammelin, T., J. Laitinen, et al. (2004). "Change in the level of physical activity from adolescence into adulthood and obesity at the age of 31 years." Int J Obes Relat Metab Disord **28**(6): 775-82.

Tammelin, T., S. Nayha, et al. (2003). "Adolescent participation in sports and adult physical activity." Am J Prev Med **24**(1): 22-8.

Tataranni, P. A., I. T. Harper, et al. (2003). "Body weight gain in free-living Pima Indians: effect of energy intake vs expenditure." Int J Obes Relat Metab Disord **27**(12): 1578-83.

Tehard, B., W. H. Saris, et al. (2005). "Comparison of two physical activity questionnaires in obese subjects: the NUGENOB study." Med Sci Sports Exerc **37**(9): 1535-41.

Telama, R., E. Leskinen, et al. (1996). "Stability of habitual physical activity and sport participation: a longitudinal tracking study." Scand J Med Sci Sports **6**(6): 371-8.

Telama, R. and X. Yang (2000). "Decline of physical activity from youth to young adulthood in Finland." Med Sci Sports Exerc **32**(9): 1617-22.

Telama, R., X. Yang, et al. (2006). "Participation in organized youth sport as a predictor of adult physical activity: a 21-year longitudinal study." Ped Exerc Sci **17**: 76-88.

Telama, R., X. Yang, et al. (1997). "Physical activity in childhood and adolescence as predictor of physical activity in young adulthood." Am J Prev Med **13**(4): 317-23.

Tell, G. S. and O. D. Vellar (1988). "Physical fitness, physical activity, and cardiovascular disease risk factors in adolescents: the Oslo Youth Study." Prev Med **17**(1): 12-24.

Thompson, A. M., P. D. Campagna, et al. (2005). "Physical activity and body mass index in grade 3, 7, and 11 Nova Scotia students." Med Sci Sports Exerc **37**(11): 1902-8.

Thompson, D. L., J. Rakow, et al. (2004). "Relationship between accumulated walking and body composition in middle-aged women." Med Sci Sports Exerc **36**(5): 911-4.

Thune, I., T. Brenn, et al. (1997). "Physical activity and the risk of breast cancer." N Engl J Med **336**(18): 1269-75.

Thune, I., I. Njolstad, et al. (1998). "Physical activity improves the metabolic risk profiles in men and women: the Tromso Study." Arch Intern Med **158**(15): 1633-40.

Timperio, A., J. Salmon, et al. (2002). Validation of adult physical activity questions for use in Australian population surveys, Commonwealth Department of Health and Ageing.

Tomkinson, G. R., L. A. Leger, et al. (2003). "Secular trends in the performance of children and adolescents (1980-2000): an analysis of 55 studies of the 20m shuttle run test in 11 countries." Sports Med **33**(4): 285-300.

Tremblay, M. S., P. T. Katzmarzyk, et al. (2002). "Temporal trends in overweight and obesity in Canada, 1981-1996." Int J Obes Relat Metab Disord **26**(4): 538-43.

Tremblay, M. S. and J. D. Willms (2000). "Secular trends in the body mass index of Canadian children." CMAJ **163**(11): 1429-33.

Treuth, M. S., N. F. Butte, et al. (2003). "Predictors of body fat gain in nonobese girls with a familial predisposition to obesity." Am J Clin Nutr **78**(6): 1212-8.

Treuth, M. S., N. Hou, et al. (2005). "Accelerometry-measured activity or sedentary time and overweight in rural boys and girls." Obes Res **13**(9): 1606-14.

Trost, S. G. (1998). The association between physical activity and cardiorespiratory fitness in children and adolescents: A meta-analytic review. Report prepared for the University of South Carolina School of Public Health. South Carolina, University of South Carolina.

Trost, S. G. (2003). Discussion Paper for the Development of Recommendations for Children's and Youths' Participation in Health Promoting Physical Activity. Canberra, Commonwealth Department of Health and Ageing.

Trost, S. G., R. R. Pate, et al. (1996). "Gender differences in physical activity and determinants of physical activity in rural fifth grade children." J Sch Health **66**(4): 145-50.

Trudeau, F., L. Laurencelle, et al. (2004). "Tracking of physical activity from childhood to adulthood." Med Sci Sports Exerc **36**(11): 1937-43.

Trudeau, F., R. J. Shephard, et al. (2001). "Changes in adiposity and body mass index from late childhood to adult life in the Trois-Rivieres study." Am J Hum Biol **13**(3): 349-55.

Trudeau, F., R. J. Shephard, et al. (2003). "Tracking of physical fitness from childhood to adulthood." Can J Appl Physiol **28**(2): 257-71.

Tucker, L. A. and M. Bagwell (1991). "Television viewing and obesity in adult females." Am J Public Health **81**(7): 908-11.

Tucker, L. A. and G. M. Friedman (1989). "Television viewing and obesity in adult males." Am J Public Health **79**(4): 516-8.

Tudor-Locke, C., B. E. Ainsworth, et al. (2001). "The relationship between pedometer-determined ambulatory activity and body composition variables." Int J Obes Relat Metab Disord **25**(11): 1571-8.

Tudor-Locke, C. and D. R. Bassett, Jr. (2004). "How many steps/day are enough? Preliminary pedometer indices for public health." Sports Med **34**(1): 1-8.

Tudor-Locke, C., D. R. Bassett, et al. (2004). "A preliminary study of one year of pedometer self-monitoring." Ann Behav Med **28**(3): 158-62.

Tudor-Locke, C., L. Burkett, et al. (2005). "How many days of pedometer monitoring predict weekly physical activity in adults?" Prev Med **40**(3): 293-8.

Tudor-Locke, C., J. E. Williams, et al. (2002). "Utility of pedometers for assessing physical activity: convergent validity." Sports Med **32**(12): 795-808.

Tudor-Locke, C., J. E. Williams, et al. (2004). "Utility of pedometers for assessing physical activity: construct validity." Sports Med **34**(5): 281-91.

Tudor-Locke, C. E. and A. M. Myers (2001). "Challenges and opportunities for measuring physical activity in sedentary adults." Sports Med **31**(2): 91-100.

Tudor-Locke, C. E. and A. M. Myers (2001). "Methodological considerations for researchers and practitioners using pedometers to measure physical (ambulatory) activity." Res Q Exerc Sport **72**(1): 1-12.

Turrell, G., B. Hewitt, et al. (2003). "Measuring socio-economic position in dietary research: is choice of socio-economic indicator important?" Public Health Nutr **6**(2): 191-200.

Twisk, J. W., H. C. Kemper, et al. (1994). "Mathematical and analytical aspects of tracking." Epidemiol Rev **16**(2): 165-83.

Twisk, J. W., H. C. Kemper, et al. (2000). "Tracking of activity and fitness and the relationship with cardiovascular disease risk factors." Med Sci Sports Exerc **32**(8): 1455-61.

Twisk, J. W., H. C. Kemper, et al. (2002). "Prediction of cardiovascular disease risk factors later in life by physical activity and physical fitness in youth: general comments and conclusions." Int J Sports Med **23 Suppl 1**: S44-9.

Twisk, J. W., H. C. Kemper, et al. (2002). "The relationship between physical fitness and physical activity during adolescence and cardiovascular disease risk factors at adult age. The Amsterdam Growth and Health Longitudinal Study." Int J Sports Med **23 Suppl 1**: S8-14.

Twisk, J. W., H. C. Kemper, et al. (1997). "Tracking of risk factors for coronary heart disease over a 14-year period: a comparison between lifestyle and biologic risk factors with data from the Amsterdam Growth and Health Study." Am J Epidemiol **145**(10): 888-98.

Twisk, J. W., H. C. Kemper, et al. (2001). "Clustering of risk factors for coronary heart disease: the longitudinal relationship with lifestyle." Ann Epidemiol **11**(3): 157-65.

Twisk, J. W. R., H. C. G. Kemper, et al. (1995). Tracking of cardiovascular disease risk factors in relation to lifestyle. The Amsterdam Growth Study: a longitudinal analysis of health, fitness and lifestyle. H. C. G. Kemper. USA, Human Kinetics.

US Department of Health and Human Services (1996). Physical activity and health: a report of the Surgeon General. Atlanta, GA, United States Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion.

USDHHS (1996). Physical activity and health: a report of the Surgeon General - Executive Summary. Atlanta, GA, United States Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion.

van Mechelen, W., J. W. Twisk, et al. (2000). "Physical activity of young people: the Amsterdam Longitudinal Growth and Health Study." Med Sci Sports Exerc **32**(9): 1610-6.

Vandongen, R., D. A. Jenner, et al. (1995). "A controlled evaluation of a fitness and nutrition intervention program on cardiovascular health in 10- to 12-year-old children." Prev Med **24**(1): 9-22.

Venn, A., R. Thomson, et al. (In Press). "Overweight and obesity from childhood to adulthood: a follow-up of participants in the 1985 Australian Schools Health and Fitness Survey." Med J Aust.

Vincent, S. D., R. P. Pangrazi, et al. (2003). "Activity levels and body mass index of children in the United States, Sweden, and Australia." Med Sci Sports Exerc **35**(8): 1367-73.

Vioque, J., A. Torres, et al. (2000). "Time spent watching television, sleep duration and obesity in adults living in Valencia, Spain." Int J Obes Relat Metab Disord **24**(12): 1683-8.

Visscher, T. L. and J. C. Seidell (2001). "The public health impact of obesity." Annu Rev Public Health **22**: 355-75.

Wake, M., K. Hesketh, et al. (2003). "Television, computer use and body mass index in Australian primary school children." J Paediatr Child Health **39**: 130-4.

Walker, S. P., E. B. Rimm, et al. (1996). "Body size and fat distribution as predictors of stroke among US men." Am J Epidemiol **144**(12): 1143-50.

Wamala, S. P., J. Lynch, et al. (2001). "Women's exposure to early and later life socioeconomic disadvantage and coronary heart disease risk: the Stockholm Female Coronary Risk Study." Int J Epidemiol **30**(2): 275-84.

Wang, Y. and X. Wang (2003). "How do statistical properties influence findings of tracking (maintenance) in epidemiologic studies? An example of research in tracking of obesity." Eur J Epidemiol **18**(11): 1037-45.

Wannamethee, S. G., A. G. Shaper, et al. (2000). "Physical activity, metabolic factors, and the incidence of coronary heart disease and type 2 diabetes." Arch Intern Med **160**(14): 2108-16.

Wareham, N. J. and K. L. Rennie (1998). "The assessment of physical activity in individuals and populations: why try to be more precise about how physical activity is assessed?" Int J Obes Relat Metab Disord **22 Suppl 2**: S30-8.

Wareham, N. J., E. M. van Sluijs, et al. (2005). "Physical activity and obesity prevention: a review of the current evidence." Proc Nutr Soc **64**(2): 229-47.

Welk, G. J., C. B. Corbin, et al. (2000). "Measurement issues in the assessment of physical activity in children." Res Q Exerc Sport **71**(2 Suppl): S59-73.

Westerterp, K. R. and M. I. Goran (1997). "Relationship between physical activity related energy expenditure and body composition: a gender difference." Int J Obes Relat Metab Disord **21**(3): 184-8.

Whitaker, R. C., J. A. Wright, et al. (1997). "Predicting obesity in young adulthood from childhood and parental obesity." N Engl J Med **337**(13): 869-73.

White, V., D. Hill, et al. (2003). "How has the prevalence of cigarette smoking changed among Australian adults? Trends in smoking prevalence between 1980 and 2001." Tob Control **12 Suppl 2**: ii67-74.

Whitt, M., S. Kumanyika, et al. (2003). "Amount and bouts of physical activity in a sample of African-American women." Med Sci Sports Exerc **35**(11): 1887-93.

Willett, W. C., J. E. Manson, et al. (1995). "Weight, weight change, and coronary heart disease in women. Risk within the 'normal' weight range." JAMA **273**(6): 461-5.

Williams, P. T. (2001). "Physical fitness and activity as separate heart disease risk factors: a meta-analysis." Med Sci Sports Exerc **33**(5): 754-61.

Williams, S. (2001). "Overweight at age 21: the association with body mass index in childhood and adolescence and parents' body mass index. A cohort study of New Zealanders born in 1972-1973." Int J Obes Relat Metab Disord **25**(2): 158-63.

Williamson, D. F., J. Madans, et al. (1993). "Recreational physical activity and ten-year weight change in a US national cohort." Int J Obes Relat Metab Disord **17**(5): 279-86.

Withers, R. T., G. J. Davies, et al. (1977). "A comparison of three W170 protocols." Eur J Appl Physiol **37**: 123-8.

World Health Organisation (1995). Physical status: the use and interpretation of anthropometry. Geneva, WHO.

World Health Organisation (1999). Obesity: preventing and managing the global epidemic. Geneva, World Health Organisation.

Wright, C. M., L. Parker, et al. (2001). "Implications of childhood obesity for adult health: findings from thousand families cohort study." BMJ **323**(7324): 1280-4.

Wyatt, H. R., J. C. Peters, et al. (2005). "A Colorado statewide survey of walking and its relation to excessive weight." Med Sci Sports Exerc **37**(5): 724-30.

Yang, X., R. Telama, et al. (2006). "Risk of obesity in relation to physical activity tracking from youth to adulthood." Med Sci Sports Exerc **38**(5): 919-25.

Yao, M., A. H. Lichtenstein, et al. (2003). "Relative influence of diet and physical activity on cardiovascular risk factors in urban Chinese adults." Int J Obes Relat Metab Disord **27**(8): 920-32.

Yoshioka, M., M. Ayabe, et al. (2005). "Long-period accelerometer monitoring shows the role of physical activity in overweight and obesity." Int J Obes (Lond) **29**(5): 502-8.

Zaninotto, P., H. Wardle, et al. (2006). Forecasting Obesity to 2010. London, Joint Health Surveys Unit, National Centre for Social Research, Dept of Epidemiology & Public Health, Royal Free & University College Medical School. **2006**.

APPENDICES

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16 February 2005

«first_name» «surname»
«address»
«state» «postcode»

Dear «first_name»

RE: Childhood Determinants of Adult Health

I am writing to invite you to take part in a follow-up study of students who participated in the 1985 Australian Schools Health and Fitness Survey. We believe you participated in the original survey when you were «age» years old and a student at «school_name» in «State_wrds». This follow-up study, known as the **Childhood Determinants of Adult Health,** is being conducted by a team of researchers based at the Menzies Research Institute in Hobart and collaborators in Melbourne. It has been funded by the National Health & Medical Research Council.

The long-term aim of this follow-up study is to determine the importance of health and fitness in childhood in predicting the risk of heart disease and diabetes in later life. In the short-term, the study will provide important new information on how health and fitness in childhood predict health problems of importance to young adults. The detailed information collected from the 1985 Australian Schools Health and Fitness Survey is unique in Australia and makes this follow-up study one of only four internationally with the capacity to answer these questions.

If you agree to participate in the study, we will first ask you to enroll as a participant by completing the enclosed brief questionnaire about yourself and providing us with information to help us contact you again.

At some time during 2005-2006, you will be asked to attend a clinic for a free health check and, subject to funding, will also be invited again ten years later. The follow-up studies will take similar measures to those taken in 1985 and you will also be asked to complete questionnaires about your health and lifestyle. Further information about the study is included in the enclosed information brochure.

Participation in the study is entirely voluntary and you may withdraw from the study at any time. All information provided for the study will remain confidential and no individual will be identifiable in reports or presentations that arise from the study.

We hope that you will agree to participate in the study. Please return the completed questionnaire and informed consent form in the reply-paid envelope, **as soon as you can**. If you do not wish to participate, please let us know.

Because it is very important that we find as many of the original 1985 survey participants as possible, we may contact you to see if you can help us establish the whereabouts, or new married names, of some of your classmates.

The Australian Electoral Commission (AEC) has provided name, address, gender and age-range information for this medical research study in conformity with sections 91(4A)(e) and 91A(2A)(c) of the *Commonwealth Electoral Act 1918* and Regulation 10 of the Electoral and Referendum Regulations. The AEC has not disclosed particulars of the occupation or dates of birth of any electors registered on the Commonwealth Electoral Roll.

If you have any questions about the study, please contact the Recruitment Co-ordinator, Beverley Curry, on our toll-free telephone number 1800 634 124.

Thank you for your cooperation.

Yours sincerely

Associate Professor Alison Venn
Chief Investigator
Childhood Determinants of Adult Health
Acting Director - Menzies Research Institute

CDAH

Who do I contact if I have questions?

If you have any questions, please call our toll-free number on 1800 634 124 during office hours. You can find more information about the study at our web site: www.menzies.utas.edu.au/Cohort/CDAH.htm and can reach us by email at CDAH@menzies.utas.edu.au.

If you have any concerns of an ethical nature or complaints about the manner in which the study is conducted, you may contact the Executive Officer of the Southern Tasmanian Health and Medical Human Research Ethics Committee.
Tel: (03) 6226 2763

Where is my class of '85?

Finding everyone from the original 1985 survey is a big task!

If you are in contact with any of your old classmates, know where they are or their new married names, we would be pleased to hear from you.

You could also help by asking your classmates to contact us or help us update our records if you know that they are no longer resident in Australia.

If you are able to help, please call us on our toll free number 1800 634 124.

The Research Team

Professor Terry Dwyer, Menzies Research Institute,Tasmania

Dr Alison Venn, Menzies Research Institute, Tasmania

Professor Paul Zimmet, International Diabetes Institute, Victoria

Professor George Patton, Centre for Adolescent Health, Victoria

Contacts

The Project Manager: Ms Marita Dalton

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www.menzies.utas.edu.au/Cohort/CDAH.htm

CDAH CHILDHOOD DETERMINANTS OF ADULT HEALTH

INFORMATION FOR PARTICIPANTS

UNIVERSITY of TASMANIA

CDAH

What is the Study about?

Heart disease and diabetes are major health problems in Australia and the rest of the world.

Much of what we know about the importance of lifestyle factors, such as diet and exercise, and the role of blood pressure and cholesterol levels, comes from research in adults.

Some studies have suggested that the early stages of heart disease and diabetes start to occur in childhood.

We need to find out more about how lifestyle and other risk factors in children and young adults affect their chance of developing heart disease and diabetes in later life.

Lots of valuable information was collected from children in the 1985 Australian Schools Health & Fitness Survey. A follow-up study of the long-term health of these children will help us to answer these important research questions.

In addition, the study will help us to understand how lifestyle and physical measures in childhood affect the health of young adults including respiratory and mental health and women's reproductive health.

Who is being asked to participate?

We hope to invite all 8,484 students who participated in the original 1985 Australian Schools Health & Fitness Survey to be in our follow-up study.

The original participants came from 109 schools around Australia, and were aged 7 to 15, with around 20 students in each age group from each school.

What will the study involve?

If you agree to participate in the study we will ask you to do the following:

- Enrol in the study now by returning your completed questionnaire and consent form and providing your contact details.
- Visit a study clinic in your nearest capital city or a regional centre for the first follow-up, which will be during 2003 – 2005.
- At the study clinic you will be asked to complete questionnaires about your medical history, current health status and lifestyle and have a free health check.
- Be part of the second follow-up ten years later in 2013 – 2015.

What do you mean by 'health check'?

The health check will include measures of your blood pressure, height, weight, waist and hip girths, and collection of blood samples. The blood samples will be used to test your blood cholesterol, sugar levels, certain hormones in women, and genetic risk factors.

We will also measure: your lung function, by getting you to blow into a machine; and your heel bone density and the health of your arteries, using a simple, painless ultrasound procedure. An exercise bicycle will be used to test your fitness.

If there are any tests you are unable to complete or prefer not to complete, we would still value your participation in all other areas.

What will happen next?

If you agree to take part in the study:

- You will receive study newsletters.
- You will be contacted again in a year or two to arrange your clinic visit.

Is the study confidential?

Yes. The information you provide will be treated confidentially.

You will be allocated an identification number so that your information can be stored in computer files without your name.

Identifiable information will not be released to anyone outside the research team and will not be used for any other purpose. You will not be identified in any reports or presentations that arise from the research.

Do I have to participate?

No. Participation is voluntary. Even if you agree to participate now, you will be able to withdraw from the study at any time, and can change your mind between now and the testing period.

CONSENT TO PARTICIPATE & FORWARD RESULTS

____, of
(First Name) (Last Name)

______________________ ______________________ ______________
(Address) (Suburb) (Postcode)

1) I have read and understood the information brochure for this study.
2) The purpose of the study, the expected length of time the examination will take, and an indication of any discomfort which may be expected, has been explained to me.
3) I understand that the clinic visit will involve collection of a blood sample, measurement of my blood pressure, lung function, weight, height, waist, hips and skin folds, ultrasound measures of my heel bone density and blood vessels, and some simple fitness tests.
4) I agree that a sample of my blood and DNA may be kept indefinitely for future studies to investigate potential links between blood factors or genes and cardiovascular disease and type 2 diabetes.
5) I understand that it is my responsibility, when asked, to inform personnel carrying out the testing if I am pregnant or have any injury or medical condition which may make it unsafe for me to carry out any of the tests.
6) I understand that all research data will be treated as confidential and no identifying information about me will be released.
7) I agree that the findings of the study may be published provided that I cannot be identified as a subject.
8) I understand that some of the results of my assessments will be given to me and/or my doctor if I wish.
9) I understand that I am free to withdraw from this study at any time.
10) I understand that the study has been approved by the Southern Tasmania Health and Medical Human Research Ethics Committee.
11) Any questions that I have asked have been answered to my satisfaction.

Signed________________________________ Date_____/_____/_____

Witness_______________________________ Date_____/_____/_____

To whom would you like your results sent? (Please tick one or both boxes)

To myself ☐ To my doctor* ☐

*If you want your results sent to your doctor, please write the name and address below:

Dr____
(Name)

____
(Street)

______________________ ______________________ ______________
(Suburb) (State) (Postcode)

ENROLMENT QUESTIONNAIRE

CDAH
CHILDHOOD DETERMINANTS of ADULT HEALTH

Your completion of this Enrolment Questionnaire will allow us to confirm your personal details and enrol you as a study participant in the Childhood Determinants of Adult Health (CDAH) Study. At each later stage of follow-up, you will be provided with additional study information and given a further opportunity to consent or decline to participate in that stage.

Instructions for completing questionnaire:
Please write in BLOCK LETTERS using a black pen (if possible).
Indicate your response by filling in the circle next to the most appropriate answer or by writing clearly in the boxes or space.

Shade circles like this ●

Not like this ⊘

Your Personal Details

Name:

First Name*

Middle Name(s)

Preferred Name
(if different to *)

Surname

Home Address:

Suburb

Postcode

Postal Address:
(if different)

Suburb

Postcode

Telephone Numbers:

Home - Work -

Mobile -

Email

Your Date of Birth: / /

0914374851

Your Marital Status:

Single	O	Separated/Divorced	O
Married	O	Widowed	O
De facto	O	Other	O

Which school were you at in 1985?

What is the highest level of formal education that you have completed?

- Primary School O
- Grade 7-9 O
- Grade 10 O
- Grade 11 O
- Grade 12 O
- Trade Certificate O
- Technical College O
- Undergraduate university studies O
- Postgraduate university studies O

What is your current employment status?

- Employed full-time O
- Employed part-time or casual O
- Unemployed O
- Home duties O
- Student O
- Permanently unable to work / Disabled O

How tall are you? cm OR ft in

How much do you weigh? kg OR st lb

Have you ever been a regular smoker? Yes O No O

(A regular smoker is someone who has smoked at least 7 cigarettes, cigars or pipes every week for at least 3 months)

Are you currently a regular smoker? Yes O No O

In general, would you say your health is:

Excellent	O	Fair	O
Very Good	O	Poor	O
Good	O		

2160374856

The name and contact details of two people who will always know where you are if you move:

CONTACT 1

First Name:

Surname:

What is their relationship to you?

Parent O Grandparent O Brother/Sister O Other relative O Friend O Other O

If other, please specify

Address:

Suburb

Postcode

Telephone Numbers:

Home - Work -

Mobile -

Email

CONTACT 2

First Name:

Surname:

What is their relationship to you?

Parent O Grandparent O Brother/Sister O Other relative O Friend O Other O

If other, please specify

Address:

Suburb

Postcode

Telephone Numbers:

Home - Work -

Mobile -

Email

9206374854

Are the tests safe?

The tests and measurements we conduct have been selected because they are safe. All CDAH staff are trained in the correct conduct of these tests. While you will be supervised carefully when undergoing the tests, we will also ask you to let the technician know if you are experiencing discomfort or finding it difficult to complete the test. You are free to withdraw from a particular test at any time.

What about discomfort?

As in any similar health check, there may be some slight discomfort resulting from the collection of the blood sample. For those participants who are asked to have the extended ultrasound test, measurement of the arm artery may involve a small amount of discomfort as a blood pressure cuff is tightened around the lower arm. However, this discomfort lasts for only a few minutes.

Do I have to complete all of the tests?

To obtain the most complete picture of your current health status, it would be preferable if you could complete all tests. However, if there are any of our tests that you are unable or prefer not to complete, we would still value your participation in all other areas.

Please let staff at the clinic know if you have concerns about any of the tests, are pregnant at the time of attending the clinic, or have any health problems.

What if I have to travel some distance to the clinic?

Reimbursement of expenses incurred in travelling to the clinic will be offered to those participants who are full-time students, who hold a healthcare card, or who have travelled greater than 50km each way to attend the clinic. If you fall into one of these categories and wish to claim reimbursement, you may obtain a claim form from the registration desk when you attend your appointment.

Can I bring my children with me?

You are encouraged to make provisions for childcare before attending the clinic as we are unable to offer any childcare facilities at the clinic and can take no responsibility for children who are in attendance. However, we understand that sometimes there is no alternative available to you and we will do our best to provide some toys for short-term entertainment!

What happens next?

Before leaving the clinic, all participants will be issued with a pedometer, which is a small instrument that measures the amount of steps taken by the wearer. We will ask you to wear this attached to your waistband during waking hours for seven days and to write down the number of steps that the pedometer records each day, and then return it to us in a pre-paid "post-pack" that will be provided.

Why do you ask so many questions?

Many of the risk factors for cardiovascular disease and diabetes are thought to be related to lifestyle issues, and cannot be assessed through physical testing. We are therefore interested in asking questions about your family history and experiences during childhood, past and current physical activity levels and current dietary patterns. When you attend the clinic we will also ask you to complete computer-administered questions relating to emotional well-being, and your alcohol and drug intake.

Why do you want to know my Medicare number?

The CDAH study needs reliable methods of finding out who develops cardiovascular disease and diabetes. One way of doing this is to access data from Medicare and the Pharmaceutical Benefits Schedule (PBS). We are seeking your permission to access Medicare and PBS data about future services used by you in relation to cardiovascular disease and/or diabetes - these include investigations and treatments and medications used.

Please be assured that the Health Insurance Commission will not release to us details of any other types of medical services you have received - ONLY those relating specifically to cardiovascular disease and/or diabetes.

The Health Insurance Commission will only release data to us with your signed consent. You can withdraw this consent at any time.

Do I get any of my results?

All participants will have a summary of selected results sent to them following attendance at the clinic. These include blood glucose and cholesterol levels, body mass index, blood pressure, lung function and bone density.

What will happen to the information collected about me?

Any information collected from you before or during the clinic is confidential and will only be handled by staff involved in the CDAH study. All cover sheets on questionnaires and clinic record sheets that have your name on them will be removed and shredded before the data is entered into the CDAH database. Data relating to participants will be transferred to a specially designed, secure database stored at the Menzies Research Institute in Tasmania. All information will be stored with ID number only - identifying information such as names will be kept separately from other data.

Can I find out my results from 1985?

Yes! When you attend the clinic, we will provide you with a summary of some of your individual results from when you took part in 1985.

THANK YOU for agreeing to take part in this important study. We look forward to meeting you at your clinic visit!

Contacts

Project Manager: Ms Marita Dalton
Recruitment Coordinator: Ms Beverley Curry

Childhood Determinants of Adult Health
Menzies Research Institute
University of Tasmania
Private Bag 23
Hobart Tas 7001

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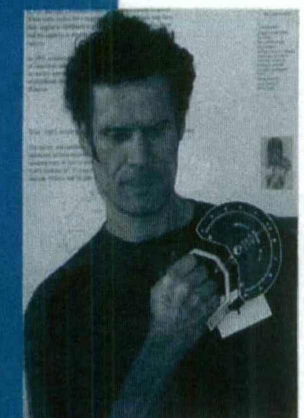
CDAH CHILDHOOD DETERMINANTS OF ADULT HEALTH



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WHAT TO EXPECT AT YOUR APPOINTMENT

CDAH

BEFORE YOUR APPOINTMENT

Some questionnaires to complete

These questionnaires are designed to obtain information on factors which may be related to cardiovascular disease and diabetes. In some instances we used standard questionnaires that are commonly used in health research.

We understand that the questionnaires are quite time consuming and that is why we have sent them to you so that you can do them at your leisure, prior to your appointment. They form a very important part of this research.

Please bring your completed questionnaires to the health check clinic with you.

If you have any questions when filling out the questionnaires, the clinic staff will be happy to answer these at your visit. Alternatively, you can call our toll-free number on 1800 634 124 for assistance.

PLEASE DO NOT HAVE ANY FOOD OR DRINK (apart from water) for 12 hours before your appointment.

This is necessary so that we can accurately measure your blood glucose and cholesterol levels. Even tea and coffee must be avoided during this time. However, if you take any regular medications it is important that you take these as usual.

If possible, please wear loose, comfortable clothing to the clinic. This will make it easier to perform some of the tests. It is also necessary to wear or bring some gym shoes with you.

AT YOUR APPOINTMENT

It will take approximately 2.5 - 3 hours to complete all the testing at the clinic. If you have chosen to attend the clinic during work time, the clinic staff can provide you with a certificate stating your attendance at the clinic.

Blood Test

A small sample of your blood (approximately 30mls) will be taken from your arm by staff members experienced in this procedure. It will be sent to a medical laboratory to determine the amounts of some blood components that may predict risk of heart disease and diabetes in the long term. These components include glucose, cholesterol, triglycerides, C-reactive protein, serum insulin and, in females, the hormones testosterone and sex hormone binding globulin. A small sample of your blood will be stored for DNA analysis. We will also store some extra blood samples for future analysis of other components that are thought to have associations with cardiovascular disease and diabetes.

Ultrasound Test of Blood Vessels

A small portable ultrasound machine will be used to visualise the carotid artery in your neck. This is a painless, safe and non-invasive procedure. Some people (selected randomly) will also be asked to have an extended procedure which will view the artery in the arm and the thickness of the heart wall.

Body Composition Measurement

You will be directed into a private area where you will have your height, weight, waist and hips measured by a technician. We will also take a measurement of body fat by using callipers to measure skinfold thickness on the arm, abdomen, hip and upper back.

Male participants will also have a quick assessment made of their pattern of hair loss (if any), by comparing their hair-line to standard pictures on a card. This is because some patterns of baldness in males have been linked to heart disease and diabetes risk.

Blood Pressure Measurement

Your blood pressure will be measured using an automatic blood pressure machine.

Breakfast

Some procedures in the clinic require you to be fasting. However, when you have completed these, we will serve you a light breakfast before asking you to do the fitness tests.

Ultrasound Test of Bone Density

Another small, portable ultrasound machine enables us to make an assessment of your bone density by placing your heel in the machine. This is a quick and painless procedure.

Computerised Questionnaires

In addition to heart disease and diabetes, we are also interested in other health issues of importance to young adults. These include issues such as anxiety, depression, and alcohol and drug use (these have also been linked to higher risks of heart disease). To ensure your privacy we will ask you to complete a questionnaire on a special laptop computer at the clinic. Only your ID number will be entered with your answers and you will not be required to show your answers to clinic staff.

Lung Function Test

The health of your lungs will be measured with a simple breathing test, where you are asked to blow into a machine.

Fitness Tests

A common fitness test will be performed using a stationary exercise bike. You will be encouraged to cycle for a total of 12 minutes while your heart rate is monitored.

The standing long jump is a good measure of muscular power. You will be asked to jump as far as you can on an exercise mat from a standing start (after being given some practice time first!).

Some instruments called 'dynamometers' will be used to measure the strength of different muscles. A technician will guide you to push or pull against these instruments.

AUSTRALIAN HEALTH & FITNESS SURVEY

1985

QUESTIONNAIRE

On the following pages you will find a number of questions about yourself, the exercise you do and your health.

We would like you to answer them all.

Please note that there are no right or wrong answers and that the answers you give are strictly private.

How to fill in your questionnaire:

1. I will read the questions with you and then you can answer each one yourself.
2. For most questions you will tick the box for the answer you want to give.

   For example:

   Do you watch television?

   Yes .... ☑

   No .... ☐
3. For other questions you will need to write the answer in the space provided. Please print clearly.
4. If you have any problems just ask me and I will help you with the answer.

Remember this is not a test, there are no right or wrong answers. What we want to know is what you do, how you think and how you feel.

COMMONWEALTH DEPARTMENT OF SPORT RECREATION & TOURISM

COMMONWEALTH DEPARTMENT OF HEALTH

NATIONAL HEART FOUNDATION OF AUSTRALIA

COMMONWEALTH SCHOOLS COMMISSION

2

Leave this column blank

1. We want to find out all the sports you have played regularly in the last year. Please include all sports you played with an organised team, group or club, or for your school, in the last year. Don't put in sports you have done as part of your P.E. classes but don't forget the sports you played during the last summer.
   Write the name of the sport in the first column and then fill in the other columns across the line with numbers. Do this for all the sports you have played in the last year.

SPORT Name of Sport	What time of year do you play this sport? Summer .. 1 Winter ... 2 Both 3	Who do you play this sport for? Club ...... 1 School ... 2 Both ...... 3 Neither ... 4	How good are you at it compared to others of your age? Better .... 1 Same .... 2 Worse ... 3	Do you like playing this sport? Lots ...... 1 Some .... 2 Little 3	Will you do it again? Yes ...... 1 No 2
e.g. GOLF	2	1	2	2	2
e.g. SWIMMING	1	3	1	1	1
....	☐	☐	☐	☐	☐
....	☐	☐	☐	☐	☐
....	☐	☐	☐	☐	☐
....	☐	☐	☐	☐	☐
....	☐	☐	☐	☐	☐
....	☐	☐	☐	☐	☐

2. In the last week what exercise have you had and what sports have you played. Begin with your travel to and from school and your Physical Education classes for the last week. Then we want to know about your school sport and any other sport or exercise you have done. Particularly anything you have done to improve your fitness.

Activity (describe fully)	How often (How many times last week?)	How long (How many hours and minutes were spent each session?) Hours : Mins	Effort (Do you huff and puff?) A lot .... 1 Some .... 2 Not much 3
Travel to school (Bicycle)	☐☐	☐ : ☐☐	☐
Travel to school (Walking)	☐☐	☐ : ☐☐	☐
School Physical Education	☐☐	☐ : ☐☐	☐
School sport: (Please print)			
....	☐☐	☐☐ : ☐☐	☐
....	☐☐	☐☐ : ☐☐	☐
Other activities: (Please print)			
....	☐☐	☐☐ : ☐☐	☐
....	☐☐	☐☐ : ☐☐	☐
....	☐☐	☐☐ : ☐☐	☐
....	☐☐	☐☐ : ☐☐	☐

Leave this column blank

3. Is your answer to the last question typical of your exercise pattern in the last month?
   - I am usually more active ☐ 1
   - The same as usual ☐ 2
   - I am usually less active ☐ 3

4. In most weeks do you get exercise or activity three or four times which makes you huff and puff and lasts at least 30 minutes each time?
   - Yes ☐ 1
   - No ☐ 2

5. What do you usually do at recess? *(Usually means 3 or more days a week.)*
   - Sit and talk to friends ☐ 1
   - Walk around the school ☐ 2
   - Run around playing sports/games ☐ 3
   - Read/study for the next classes ☐ 4
   - Nothing much ☐ 5
   - Other (Please print) ....

6. What do you usually do at lunch time? *(Usually means 3 or more days a week.)*
   - Sit and talk to friends ☐ 1
   - Walk around the school ☐ 2
   - Ride or walk home for lunch ☐ 3
   - Train for school sports teams ☐ 4
   - Play sport/games on the oval or in the school grounds ☐ 5
   - Study or do homework ☐ 6
   - Other (Please print) ....

7. Do you enjoy School Physical Education Classes?
   - Very much ☐ 1
   - Quite a lot ☐ 2
   - Sometimes ☐ 3
   - Not much ☐ 4
   - Not at all ☐ 5
   - We don't have School Physical Education ☐ 6
   - I don't do Physical Education ☐ 7

8. Do you enjoy School Sports?
   - Very much ☐ 1
   - Quite a lot ☐ 2
   - Sometimes ☐ 3
   - Not much ☐ 4
   - Not at all ☐ 5
   - We don't have School Sport ☐ 6
   - I don't do Sport ☐ 7

9. Do you enjoy Physical Activity? *(Vigorous playing or exercise that you do by choice)*
   - Yes ☐ 1 Why/Why not: ....
   - No ☐ 2

Leave this column blank

10. How fit do you think you are compared to others of your age?
    - Fitter than most ☐ 1
    - About average fitness ☐ 2
    - Not as fit as most ☐ 3

11. Is your health usually?
    - Very good ☐ 1
    - Good ☐ 2
    - Average ☐ 3
    - Poor ☐ 4
    - Very poor ☐ 5

12. Do you enjoy school?
    - Yes, all the time ☐ 1
    - Yes, most of the time ☐ 2
    - Sometimes Yes/sometimes No ☐ 3
    - Not very often ☐ 4
    - Never ☐ 5

13. How good are you at school work compared to others of your age?
    - Better than most ☐ 1
    - About the middle ☐ 2
    - Not as good as most ☐ 3

14. What time did you go to bed and turn out the lights last night? *(For example 10:35)*
    ☐☐:☐☐ Hours Mins

15. What time did you wake up this morning? *(For example 08:15)*
    ☐☐:☐☐ Hours Mins

16. Here is a list that describes some of the ways people feel at different times. During the past few weeks, how often have you felt (Tick one box on each line.)

	Often	Sometimes	Never
(a) On top of the world?	☐	☐	☐
(b) Very lonely or remote from other people?	☐	☐	☐
(c) Particularly excited or interested in something?	☐	☐	☐
(d) Depressed or unhappy?	☐	☐	☐
(e) Pleased about having accomplished something?	☐	☐	☐
(f) Bored?	☐	☐	☐
(g) Proud because someone complimented you on something you had done?	☐	☐	☐
(h) So restless you couldn't sit long in a chair?	☐	☐	☐
(i) That things were going your way?	☐	☐	☐
(j) Upset because someone criticised you?	☐	☐	☐

Leave this column blank

17. Have you ever smoked even part of a cigarette?
- No .... ☐ 1
- Yes, just a few puffs .... ☐ 2
- Yes, I have smoked fewer than 10 cigarettes in my life .... ☐ 3
- Yes, I have smoked more than 10 cigarettes in my life .... ☐ 4

18. How many cigarettes have you smoked in the last 7 days? ☐☐☐

19. How long have you been smoking regularly? *(Regularly means 1 or more times a week.)*
- I don't smoke .... ☐ 1
- Just started .... ☐ 2
- 1 month up to 6 months .... ☐ 3
- 7 months up to 1 year .... ☐ 4
- 1 year up to 2 years .... ☐ 5
- 2 years up to 4 years .... ☐ 6
- More than 4 years .... ☐ 7

20. How many people smoke at home? *(If you smoke — do not include yourself.)*

Number of persons ☐

21. Do you think you will be smoking this time next year?
- Yes .... ☐ 1
- No .... ☐ 2
- Don't know .... ☐ 3

22. Please say what you think about the following statements about smoking.

	Agree	Disagree	Don't know
(a) It makes you catch cold easily	☐	☐	☐
(b) It slows your circulation and makes your fingers cold	☐	☐	☐
(c) It keeps you alert	☐	☐	☐
(d) It makes you unable to play sport well	☐	☐	☐
(e) It makes your breathing difficult	☐	☐	☐
(f) It can cause lung cancer	☐	☐	☐
(g) It calms your nerves	☐	☐	☐
(h) It can cause heart disease	☐	☐	☐
(i) It gives you bad breath	☐	☐	☐
(j) It keeps you slim	☐	☐	☐
(k) It is addictive (habit forming)	☐	☐	☐

Leave this column blank

23. How often do you usually drink alcohol?
- I don't drink alcohol .... ☐ 1
- Less than once a week .... ☐ 2
- On 1 or 2 days a week .... ☐ 3
- On 3 or 4 days a week .... ☐ 4
- On 5 or 6 days a week .... ☐ 5
- Every day .... ☐ 6

24. Do you usually eat something before starting school? *(Usually means 4 or more times a week.)*
- Yes .... ☐ 1
- No .... ☐ 2

25. In your opinion how important is it to you to —

	Very important	Of some importance	Of little importance	Not important
(a) See a dentist once a year	☐	☐	☐	☐
(b) Have a doctor's checkup	☐	☐	☐	☐
(c) Know about your body and how it works	☐	☐	☐	☐
(d) Have a good night's sleep	☐	☐	☐	☐
(e) Eat a good diet	☐	☐	☐	☐
(f) Be a non-smoker	☐	☐	☐	☐
(g) Have a good body/figure	☐	☐	☐	☐
(h) Exercise regularly	☐	☐	☐	☐
(i) Not be fat	☐	☐	☐	☐
(j) Have friends	☐	☐	☐	☐
(k) Not be stressed and worried	☐	☐	☐	☐
(l) Not drink alcohol or only drink a little	☐	☐	☐	☐
(m) Know about fitness and how to stay fit	☐	☐	☐	☐

26. How well can you do the following?

	Never tried	Can't do	Can do about average	Can do very well
(a) Play a musical instrument	☐	☐	☐	☐
(b) Ride a horse	☐	☐	☐	☐
(c) Play tennis	☐	☐	☐	☐
(d) Swim 100 metres non-stop	☐	☐	☐	☐
(e) Play a round of golf	☐	☐	☐	☐
(f) Ride on a surfboard/sailboard	☐	☐	☐	☐
(g) Ice or roller skate	☐	☐	☐	☐
(h) Play squash/badminton or racquetball	☐	☐	☐	☐
(i) Play video games	☐	☐	☐	☐
(j) Play billiards/pool or snooker	☐	☐	☐	☐
(k) Ride on a skateboard	☐	☐	☐	☐

Leave this column blank

27. In what suburb/town do you live? *(Shire if you live on a farm.)*

....

28. When were you born? (eg 06 / May / 1970) ☐☐ / .... / 1 9 ☐☐
day month year — day month year

29. What sex are you?

- Male .... ☐ 1
- Female .... ☐ 2

30. In what country were you born? *(If you don't know the country put the city or town.)*

....

31. In which Australian State or Territory were you born?

- Born outside Australia .... ☐ 0
- A.C.T. .... ☐ 1
- New South Wales .... ☐ 2
- Victoria .... ☐ 3
- Queensland .... ☐ 4
- South Australia .... ☐ 5
- Western Australia .... ☐ 6
- Tasmania .... ☐ 7
- Northern Territory .... ☐ 8
- Don't know .... ☐ 9

32. How many years since you first arrived in Australia? ☐☐ years

In the next question, when we ask about your brothers and sisters please include step-brothers and step-sisters.

33. How many older brothers do you have at home? .... ☐
How many older sisters do you have at home? .... ☐
How many younger brothers do you have at home? .... ☐
How many younger sisters do you have at home? .... ☐

The next two questions are about where your natural parents (not your step-parents) were born. If you don't know the country, give the city or town, if you don't know write in "don't know".

34. In what country was your father born? ....

35. In what country was your mother born? ....

36. Do you speak a language, other than English, at home?

- No, English only .. ☐ 1
- Yes, we speak ....

Leave this column blank

The rest of the questions ask about your home and parents. By father we also mean stepfather or male guardian. For mother we also want you to include stepmother or female guardian.

37. During the school week, where do you live?

- At home with your mother and father .... ☐ 1
- At home with your mother .... ☐ 2
- At home with your father .... ☐ 3
- In a boarding school/house .... ☐ 4

38. Does your mother or father smoke at home?

- No .... ☐ 1
- Yes, both smoke .... ☐ 2
- Yes, mother .... ☐ 3
- Yes, father .... ☐ 4

39. Does your father exercise regularly (2 or more times a week)?
(For example does he — jog, play sport, do exercises, go to a gym, do aerobics.)

- Yes .... ☐ 1
- No .... ☐ 2
- Don't know .... ☐ 3

What activity does he do? ....

40. Does your mother exercise regularly (2 or more times a week)?
(For example does she — jog, play sport, do exercises, go to a gym, do aerobics.)

- Yes .... ☐ 1
- No .... ☐ 2
- Don't know .... ☐ 3

What activity does she do? ....

Height & Weight Measurement

Equipment: Stadiometer, Heine portable scales, Baseboard for scales

Eligibility: Participants who are chairbound should not have their height and weight taken. Similarly, if after discussion with a participant it becomes clear that they are too unsteady on their feet for these measurements, do not attempt to take them. In addition, pregnant women are not eligible for weight as this is clearly affected by their condition.

Procedure: ***Height Measurement***

Installing the Leicester Height Measure
Slot the white upright sections firmly together and ensure that the bottom section locks into the blue base. Slide on the measuring arm and position the 2 white stabilizers as required (diagram 1).

Ensure the stabilizers stay clear of the joins. The base should be placed on a firm uncarpeted surface with the stabilizers resting against a wall/door to give the Leicester rigidity.

N.B. The metric and imperial scales are calibrated to take account of the 3cm difference between the black measurement arrow and the flat surface of the measuring arm.

Diagram 1

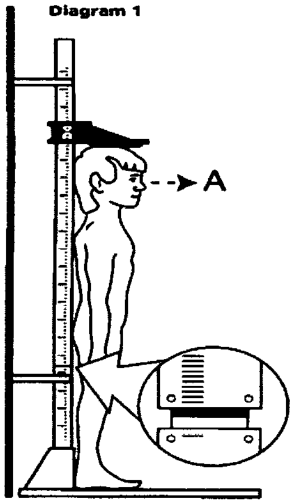
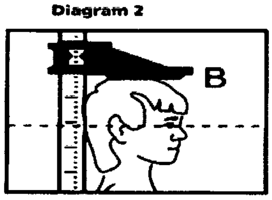


Diagram 2



1. Stand subject on the "feet" preferably barefoot with his/her heels together and touching the backstop. The spine at pelvis and shoulder level should touch the upright. Shoulders should be relaxed, arms to the side. Remove headgear (bows, ribbon etc.) where possible.
2. Lower the measuring arm onto the head and position the head so that an imaginary horizontal line runs between the ear hole and the lower border of the eye socket (see diagram 2).
3. Ask the subject to stand up straight.
4. Read off the metric height to the last completed millimeter. Do not round up! Measure with care.
5. Record the height in the boxes provided on the Data Record Form.

Additional points:

- If the subject cannot stand upright with their back against the stadiometer and have their heels against the rod (e.g., those with protruding bottoms) then give priority to standing upright.
- If the subject has a hairstyle which stands well above the top of their head, bring the head plate down until it touches the hair. With some hairstyles you can compress the hair to touch the head. If it is a hairstyle that can be altered, e.g., a bun, if possible, ask the subject to change/undo it.
- If the subject is tall, it can be difficult to line up the Frankfort Plane. When you think that the plane is horizontal, take one step back to check from a short distance that this is the case.

Weight Measurement

1. Turn scales on before subject steps on. Scales will automatically re-zero.
2. Ask subject to remove shoes & any heavy clothing, such as jackets, & to remove any heavy articles from pockets such as keys, wallets. It is acceptable to leave socks on.
3. Ask subject to step onto scales, look forward (not down) with their hands by their side, and to keep as still as possible.
4. Write down reading, recording to the nearest 0.1 kg.

Waist Measurement

Equipment: Lufkin steel (non-stretch) tape measure

Eligibility: All subjects will have waist and hip circumference measurements performed except those who are pregnant, are chairbound or have a colostomy/ileostomy.

Procedure:

a) If possible, without embarrassing the subject, ensure that the following items of clothing are removed:
   - All outer layers of clothing, such as jackets, heavy/baggy jumpers, cardigans & waistcoats.
   - Shoes with heels.
   - Tight garments intended to alter the shape of the body, such as corsets, lycra body suits and support tights.
   - If the subject is wearing a belt, ask them if it would be possible to remove it or loosen it for the measurement (if necessary).
   - Ask subject to empty pockets of heavy items (e.g. keys).

b) Ensure that the subject is standing erect in a relaxed manner and breathing normally. Weight should be balanced evenly on both feet.

c) If possible, either kneel or sit on a chair to the side of the subject.

d) If the subject is large, ask him/her to pass the tape around rather than having to 'hug' them.

e) Measure and record the waist circumference, followed by the hip circumference. Repeat each 3 times. If the first two scores are the same, it is not necessary to take the third measurement.

Waist Circumference

The waist girth is taken at the level of **the narrowest point** between the lower costal (10^{th} rib) border and the iliac crest. An approximate indicator of this level may be ascertained by asking the subject to bend sideways. Do not try to avoid the effects of waistbands by measuring the circumference at a different position or by lifting or lowering clothing items. For example, if the subject has a waistband at the correct level of the waist (midway between the lower rib margin and the iliac crest), then ask the subject to move the waistband, or measure the waist circumference over the waistband. If you believe that clothing, posture or any other factor is significantly affecting the waist measurement, record this on the data record form.

1. Ask the subject to assume a relaxed standing position with the arms folded across the thorax.
2. Stand in front of the subject, while the subject abducts (lifts) the arms slightly, allowing the tape to be passed around the subject's abdomen.
3. The stub of the tape and the housing are then both held in the right hand while you adjust the level of the tape at the back to ensure that it is level with the adjudged level of the narrowest point, with your left hand. (This will be easier if you are kneeling or sitting on a chair to the side of the subject).
4. Instruct the subject to lower their arms to the relaxed position. Readjust the tape to ensure that it has not slipped & is not too tight on the skin (i.e., does not indent the skin).
5. Ask the subject to breathe out normally and to look straight ahead (to prevent holding of one's breath). Take the measurement at the end of a normal expiration, recording measurement to the nearest 0.5 centimetres.

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SECTION A: CURRENT ACTIVITIES

The following questions will ask you about the time you spent being physically active in the last 7 days. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Please answer each question even if you do not consider yourself to be an active person.

Think about all the **vigorous** and **moderate** activities that you have done **in the last 7 days.**

- **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal.
- **Moderate** activities refer to activities that take moderate physical effort and make you breathe **somewhat** harder than normal

PART 1: WORK RELATED PHYSICAL ACTIVITY
The first section is about your work. This includes paid jobs, farming, volunteer work, course work, and any other unpaid work that you did outside your home.

Do not include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family. We ask about these in Part 3.

1. Do you currently have a job or do any unpaid work outside your home?

   No O --> **SKIP TO PART 2, TRANSPORTATION**

   Yes O

The next questions are about all the physical activity you did in the last 7 days as part of your paid or unpaid work. This does not include travelling to and from work.

2. During the **last 7 days**, on how many days did you do vigorous physical activities like heavy lifting, digging, heavy construction, or climbing up stairs **as part of your work**? Think about only those physical activities that you did for **at least 10 minutes** at a time.

   ☐ days per week

   O No vigorous job-related physical activity --> **SKIP TO Question 4**

3. How much time did you usually spend on one of those days doing vigorous physical activities as part of your work?

   ☐☐ hours ☐☐ minutes **Per day**

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4. Again, think about only those physical activities that you did for **at least 10 minutes** at a time. During **the last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads as part of your work? *Please DO NOT include walking.*

☐ days per week

O No moderate job-related physical activity --> **SKIP TO Question 6**

5. How much time did you **usually** spend on **one** of those days doing **moderate** physical activities as part of your work?

☐☐ hours ☐☐ minutes **Per day**

6. During the last 7 days, on how many days did you walk for **at least 10 minutes** at a time as part of your work? Please do not count any walking you did to travel to, or from work.

☐ days per week

O No job-related walking--> **Skip to PART 2: TRANSPORTATION**

7. How much time did you usually spend on **one** of those days **walking** as part of your work?

☐☐ hours ☐☐ minutes **Per day**

PART 2: TRANSPORTATION PHYSICAL ACTIVITY
These questions are about how you travelled from place to place, including to places like work, stores, movies, and so on.

8. During the last 7 days, on how many days did you travel **in a motor vehicle** like a train, bus, car, or tram?

☐ days per week

O No motor transport --> **SKIP TO Question 10**

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9. How much time did you usually spend in a motor vehicle on one of those days.

☐☐ hours ☐☐ minutes **Per day**

Now think only about the <u>cycling</u> and <u>walking</u> you might have done to travel to and from work, to do errands, or to go from place to place.

10. During **the last 7 days**, on how many days did you **cycle** for **at least 10 minutes** at a time to go from place to place?

☐ days per week

O No cycling from place to place --> SKIP TO Question 12

11. How much time did you usually spend on **one** of those days **cycling** from place to place?

☐☐ hours ☐☐ minutes Per day

12. During the last 7 days, on how many days did you **walk** for **at least 10 minutes** at a time to go from place to place?

☐ days per week

O No walking from place to place --> SKIP TO PART 3: HOUSEWORK, MAINTENANCE AND CARING FOR FAMILY

13. How much time did you usually spend on **one** of those days **walking** from place to place?

☐☐ hours ☐☐ minutes Per day

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PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY
This section is about some of the physical activities you might have done in the last 7 days in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family

YARD WORK:

14. Think about only those physical activities that you did for **at least 10 minutes** at a time. During **the last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, chopping wood, shovelling snow, or digging in the garden or yard?

☐ days per week

O No vigorous yard activity --> **SKIP TO Question 16**

15. How much time did you usually spend on **one** of those days doing **vigorous** physical activities **in the garden or yard**?

☐☐ hours ☐☐ minutes **Per day**

16. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do **moderate** activities like carrying light loads, sweeping, washing windows, and raking **in the garden or yard**?

☐ days per week

O No moderate yard activity --> **SKIP TO Question 18**

17. How much time did you usually spend on **one** of those days doing **moderate** physical activities **in the garden or yard**?

☐☐ hours ☐☐ minutes **Per day**

HOUSEWORK:

18. Once again, think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do **moderate** activities like carrying light loads, washing windows, scrubbing floors and sweeping **inside your home**?

☐ days per week

O No moderate activity at home --> **SKIP TO PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY**

19. How much time did you usually spend on **one** of those days doing **moderate** physical activities **inside your home**?

☐☐ hours ☐☐ minutes **Per day**

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PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY
This section is about all the physical activities that you did in the last 7 days solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

20. Not counting any walking you have already mentioned, during **the last 7 days**, on how many days did you **walk** for **at least 10 minutes** at a time in your leisure time?

☐ days per week

O No leisure walking --> **SKIP TO Question 22**

21. How much time did you usually spend on **one** of those days **walking** in your leisure time?

☐☐ hours ☐☐ minutes **Per day**

22. Think about only those physical activities that you did for **at least 10 minutes** at a time. During **the last 7 days**, on how many days did you do **vigorous** physical activities like: aerobics, running, fast bicycling, or fast swimming in your leisure time?

☐ days per week

O No vigorous activity in leisure time --> **SKIP TO Question 24**

23. How much time did you usually spend on **one** of those days doing vigorous physical activities in your leisure time?

☐☐ hours ☐☐ minutes **Per day**

24. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do **moderate** physical activities like: bicycling at a regular pace, swimming at a regular pace, and doubles tennis in your leisure time?

☐ days per week

O No moderate activity in leisure time --> **SKIP TO PART 5: TIME SPENT SITTING**

25. How much time did you usually spend on **one** of those days doing **moderate** physical activities in your leisure time?

☐☐ hours ☐☐ minutes **Per day**

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PART 5: TIME SPENT SITTING

These last questions are about the time you spend sitting while at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television.

Do not include any time spent sitting in a motor vehicle that you have already told us about.

26. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekday**?

☐☐ hours ☐☐ minutes **Per day**

27. During the last 7 days, how much time did you usually spend **sitting** on a **weekend** day?

☐☐ hours ☐☐ minutes **Per day**

We are also interested in finding out about your television viewing and computer use habits

28. Please estimate the total time **during the last week** that you spent watching television, videos or DVD's when it was the **main** activity that you were doing.
For example, you should not include time when the television was switched on and you were preparing a meal or ironing.

Total time Monday to Friday ☐☐ hours ☐☐ minutes **Total time Saturday and Sunday** ☐☐ hours ☐☐ minutes

29. Please estimate how often **in a usual week** you would have each of the following while watching television

	Always (every day)	Usually (5-6 times/week)	Sometimes (3-4 times/week)	Rarely (1-2 times/week)	Never
A Meal	O	O	O	O	O
A Snack	O	O	O	O	O
A soft drink	O	O	O	O	O
An alcoholic drink	O	O	O	O	O

I do not watch television O

30. Please estimate the total time **during the last week** that you spent using a computer during the week and on weekends (this might be a personal computer at home or work, Playstation, X-box, Gameboy, etc).

Total time Monday to Friday ☐☐ hours ☐☐ minutes **Total time Saturday and Sunday** ☐☐ hours ☐☐ minutes

PEDOMETER PROTOCOL

Equipment: Pedometer (Yamax Digiwalker SW-200)
Participant diary card and instruction sheet
Reply paid postpak

Eligibility: All participants should be able to wear a pedometer.

Procedure:

Fitting the Pedometer

1. Show the participant what a pedometer is and explain that it is a small device worn on the hip that measures the number of steps taken
2. Explain that pedometers are being used in this study to estimate the amount of daily physical activity undertaken by each participant
3. Explain that the pedometer needs to be worn for seven (7) consecutive days starting the next day (the participant can commence wearing the pedometer on the day of administration, but they must not record the number of steps taken for that day). Explain that if a day is missed, this needs to be recorded in the participant's pedometer diary. If this occurs, the participant should continue to wear the pedometer until data has been collected for a total of seven days
4. Show the participant how to clip the pedometer firmly to their waistband or belt of trousers/skirt on their right leg. This must be attached above the point where the crease in a pair of trousers would normally be and the pedometer should sit flat and straight (anterior mid-line of the thigh).
5. Read through the instruction sheet with the participant and ensure that they understand all instructions. Ensure that the participant understands how to reset the pedometer.
6. Read through the pedometer diary with the participant and ensure that they understand how to complete the diary. Remind the participant to start completing the diary tomorrow. Explain to the participant that if there are problems with the pedometer to contact the research team or to note the problem in their pedometer diary.
7. Remind the participant to reset the pedometer every morning by pressing the yellow button and explain the importance of closing the pedometer firmly (the pedometer will not work if left open).
8. Emphasise that it is important for the participant to "do what they normally do" – we do not want participants to do anything different while they are wearing their pedometer.
9. If a participant asks how many steps per day they should be aiming for, emphasise again that they should be aiming to do the same amount of activity that they normally do – we are interested in their usual activity levels
10. On the pedometer record sheet, record the date, sheet number and location, as well as the following information:
    - Participant ID (barcode)
    - Pedometer ID
    - Participant signature
11. In the participant pedometer diary, record the following information:
    - Participant ID (barcode)
    - Pedometer ID
12. Issue participant with the pedometer, pedometer diary and instruction sheet, and reply paid postpak (for return of pedometer)
13. Emphasise the importance of prompt return of the pedometer and completed diary in the postpak at the end of the seven days. Explain that we have a limited number of pedometers and we need them returned as quickly as possible to ensure that everyone gets a chance to wear one.
14. Ensure that any questions the participant may have are answered and draw attention to the contact details of the research team on the instruction sheet.

Pedometer Follow-up
For pedometers returned:
1. Complete central pedometer database with:
   - Participant ID (barcode)
   - Pedometer number
   - Date of return
2. Check the pedometer battery and calibrate the pedometer (see "Pedometer Quality Control – Calibration and Batteries")

For pedometers not returned:
1. Wait two weeks from the date the pedometer was given to the participant
2. Contact participant to see if they:
   - have had problems with the pedometer
   - finished the seven days measurement
   - lost the reply paid postpak
   - have not got around to returning the pedometer
3. If the participant:
   - Has had problems – try to work out the problem over the telephone
   - Has unfinished measurement – explain the importance of seven days monitoring and emphasise that the seven days should be completed as soon as possible
   - Has lost postpak – check address and send new reply paid package to participant. Emphasise the importance of returning the pedometer so that other participants can use it.
   - Has forgotten to return – emphasise the importance of returning the pedometer so that other participants can use it
4. If after three weeks the participant has still not returned their pedometer, re-contact by telephone and revisit steps 2 and 3. Continue to contact the participant on a weekly basis until the pedometer is returned.
5. If after three telephone contacts the pedometer has still not been returned, send a new postpak with standardised reminder letter.

Pedometer Quality Control – Calibration and Batteries
All pedometers should be calibrated and battery-checked upon return from each participant. The date of these procedures should be recorded in the central database for each pedometer checked.

<u>Calibration:</u> Open the front of the pedometer and press the reset button so the display reads "0". Close the pedometer and walk for 100 steps. Open the pedometer and check the display. The number should be within 5% of the actual number of steps taken (i.e. 95-105 steps). If the pedometer is not within 5% of the actual number of steps taken, repeat process. If the pedometer is still not within 5% of the actual number of steps taken, contact Brian Fox, National Sales Manager, 02 9642 9203, Dick Smith Electronics. All pedometers have a 1-year warranty from the date of purchase.

<u>Batteries</u>: To check the battery, open the pedometer and ensure that the display is clear and has not begun to dim. If the display begins to dim, the battery requires changing. The usual battery life is 2-3 years and an LR-44 type photo/electric battery should be used. To replace the battery, place a coin in the slot on the bottom of the pedometer (opposite the end where you open it). Slowly twist the coin. The cover will pop off. Replace the "dead" battery with a new one making sure that the positive side faces you. When replacing the cover, make sure that it is properly aligned and then snap it shut. Check to see that the cover is secure. Hold down the reset button for about 5 seconds and when the display goes blank, remove your fingers from the buttons. The display should show "88888" then "0". Batteries can either be purchased from a local Dick Smith/Tandy outlet or from Dick Smith Electronics Head Office (Brian Fox, National Sales Manager, 02 9642 9203).

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Ped ID

CHILDHOOD DETERMINANTS OF ADULT HEALTH

PEDOMETER DIARY

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(Bar code ID here)

Day	Date	Start Time	End Time	Display Number	Time spent active but no pedometer	Activities participated in while NOT wearing pedometer	Circumstances that may have affected pedometer reading
1	: :	O am O pm	O am O pm		Hrs : Min		
2	: :	O am O pm	O am O pm		Hrs Min		
3	: :	O am O pm	O am O pm		Hrs Min		
4	: :	O am O pm	O am O pm		Hrs Min		
5	: :	O am O pm	O am O pm		Hrs Min		
6	: :	O am O pm	O am O pm		Hrs Min		
7	: :	O am O pm	O am O pm		Hrs Min		

REMEMBER TO RESET YOUR PEDOMETER EVERY MORNING

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CDAH
CHILDHOOD DETERMINANTS of ADULT HEALTH

PEDOMETER INSTRUCTIONS

1. After you get dressed in the morning, clip the pedometer firmly on your belt, trousers, skirt, etc. To make sure results are accurate, clip the pedometer on your RIGHT-HAND side, above the point where the crease in a pair of trousers would normally be.

2. Open the front case of the pedometer and press the yellow **RESET** button.

3. Close the case and record the date **(DATE)** and time of day **(START TIME)** in your pedometer diary.

4. At the end of the day, before changing for bed, open the front case of the pedometer (without removing it from your clothing) and record the time of day **(END TIME)** and the number displayed on the screen **(DISPLAY NUMBER)** in your pedometer diary.

   Please also note on the diary:
   - If you removed the pedometer while being physically active (duration and reason) i.e. swimming
   - Any circumstances that may affect your pedometer reading, including for example, travelling long distances on a bumpy road or illness.

5. Please make sure you have completed all relevant sections in your pedometer diary.

6. You need to wear the pedometer for **SEVEN** consecutive days. If you miss a day please wear your pedometer the following day as normal. When you have done this, place the pedometer and your pedometer diary card inside the reply paid post-pak provided.

   Please send the pedometer back as soon as possible as it is needed for other participants in the study.

Thank you for your co-operation

If you have any questions or problems, please phone the CDAH team on 1800 634 124 (toll free)

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SECTION A: This section asks you some questions about yourself. You may feel you have already answered these questions in our enrolment questionnaire, however your circumstances may have changed since you completed our enrolment questionnaire.

1. **Todays date** ☐☐ / ☐☐ / ☐☐

2. **What sex are you?** O Male O Female

3. **What is your date of birth?** ☐☐ / ☐☐ / ☐☐

4. **What is your current marital status?**

O Single

O Married

O De facto

O Separated/Divorced

O Widowed

O Other ______ (please specify)

5. **What is the highest level of education you have completed? (Select only one answer)**

O Primary School

O Year 7, 8 or 9 or equivalent

O Year 10 or equivalent

O Year 11 or equivalent

O Year 12 or equivalent

O Trade/apprenticeship (e.g. hairdresser, chef)

O Certificate/diploma (e.g. child care, technician)

O University Degree

O Higher University Degree (e.g. Grad Dip, Masters, PhD)

O Other ______ (please specify)

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6. **What is your main source of income? (Select only one answer)**

- O Wages or salary
- O Own business or share in partnership
- O A government pension or cash benefit
- O Superannuation
- O Investment/ Interest
- O Other income ______ (please specify)

7. **What is your main occupation NOW (Select only one answer)**

Manager or administrator (e.g. magistrate, farm manager, general manager, director of nursing, school principal) ---------- O

Professional (e.g. scientist, doctor, registered nurse, allied health professional, teacher, artist) ---------- O

Associate professional (e.g. technician, manager, youth worker, police officer) ---------- O

Tradesperson or related worker (e.g. hairdresser, gardener, florist) ---------- O

Advanced clerical or service worker (e.g. secretary, personal assistant, flight attendant, law clerk) ---------- O

Intermediate clerical, sales or service worker (e.g. typist, word processing/data entry operator, receptionist, child care worker, nursing assistant, hospitality worker) ---------- O

Intermediate production or transport worker (e.g. sewing machinist, machine operator, bus driver) ---------- O

Elementary clerical, sales or service worker (e.g. filing/mail clerk, parking inspector, sales assistant, telemarketer, housekeeper) ---------- O

Labourer or related worker (e.g. cleaner, factory worker, general farm hand, kitchen hand) ---------- O

No paid job ---------- O

SECTION F: This section is about smoking tobacco

1. **Over your lifetime, have you smoked at least 100 cigarettes, or a similar amount of tobacco?**

O No --> **SKIP TO SECTION G (Page 20)**

O Yes

2. **How often do you now smoke cigarettes, cigars, pipes or any other tobacco products?**

O Daily

O At least once a week (but not daily) -->**Skip to Question 7**

O Less often than weekly -->**Skip to Question 7**

O Not at all -->**Skip to Question 7**

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SECTION G: These questions are about your life when you were growing up <u>until the age of 12</u>. They are mostly about your parents or other adults who you lived with and who were responsible for you.

1. This question is about only the people who lived in the same house as you and were like parents to you for <u>most</u> of the time <u>until you turned 12</u>.

1a) Did you live in the same house as your <u>father</u> or another male who was like a father to you?

O No --> Skip to question 1c

O Yes

<u>IF YES</u>

1b) What is the <u>highest</u> level of education completed by your father (or other male who lived with you and was like a father to you)

O No schooling

O Primary School only

O Year 7, 8 or 9 or equivalent

O Year 10 or equivalent

O Year 11 or equivalent

O Year 12 or equivalent

O Trade/apprenticeship (e.g. hairdresser, chef)

O Certificate/diploma (e.g. child care, technician)

O University Degree

O Higher University Degree (e.g. Grad Dip, Masters, PHD)

O Other (please specify)

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1c) **Did you live in the same house as your mother or another female who lived with you and was like a mother to you?**

O No -->**Skip to question 2**

O Yes

IF YES

1d) **What is the highest level of education completed by your mother (or other female who lived with you and was like a mother to you)**

O No schooling

O Primary School only

O Year 7, 8 or 9 or equivalent

O Year 10 or equivalent

O Year 11 or equivalent

O Year 12 or equivalent

O Trade/apprenticeship (e.g. hairdresser, chef)

O Certificate/diploma (e.g. child care, technician)

O University Degree

O Higher University Degree (e.g. Grad Dip, Masters, PHD)

O Other (please specify)

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2. **What was the MAIN occupation of your <u>father</u> (or other male who lived with you and was like a father to you), and your <u>mother</u> (or other female who lived with you and was like a mother to you) <u>until you turned 12</u>?** ***Please only select one answer for your father and one answer for your mother.***

Occupation	Father	Mother
Manager or administrator (e.g. magistrate, farm manager, general manager, director of nursing, school principal	o	o
Professional (e.g. scientist, doctor, registered nurse, allied health professional, teacher, artist)	o	o
Associate professional (e.g. technician, manager, youth worker, police officer)	o	o
Tradesperson or related worker (e.g. hairdresser, gardener, florist)	o	o
Advanced clerical or service worker (e.g. secretary, personal assistant, flight attendant, law clerk)	o	o
Intermediate clerical, sales or service worker (e.g. typist, word processing/ data entry operator, receptionist, child care worker, nursing assistant, hospitality worker)	o	o
Intermediate production or transport worker (e.g. sewing machinist, machine operator, bus driver)	o	o
Elementary clerical, sales or service worker (e.g. filing/mail clerk, parking inspector, sales assistant, telemarketer, housekeeper)	o	o
Labourer or related worker (e.g. cleaner, factory worker, general farm hand, kitchenhand)	o	o
No paid job	o	o

Appendix 13a

Chapter 3: Literature Summary Tables

Table 1: Objectively measured physical activity & adiposity in childhood: a summary of prospective studies

Study	N, Sex (Age at Baseline)	Follow-Up (f/up)	Measure of PA/SB	Measure of Adiposity	Significant Findings	Adjustments	Overall Effect*
USA (Johnson *et al.* 2000)	36 M & 79 F (4.6-11.0 years)	3-5 years	DLW technique	DXA	Energy expenditure was not associated with a lower rate of increase in adiposity	Baseline fat mass, lean tissue mass, age, Tanner stage, ethnicity	0
USA (Moore *et al.* 2003)	103 M & F (4 years)	8 years	Caltrac accelerometers (3-5 days, twice/year)	Measured height & weight; 5 skinfolds	Children in the highest PA third had lower BMI & skinfolds at follow-up than children in the lowest third. BMI & skinfold increases were smallest in the highest vs lowest third	Sex, age baseline BMI	-
USA (Treuth *et al.* 2003)	88 F (8 years)	2 years	24-hr calorimetry & DLW technique	Measured height & weight (BMI) & DXA	Energy expenditure was positively associated with body fat, although the effect size was small (0.002 increase in %BF)	Time of measurement, ethnicity, Tanner stage, group, %BF	+
USA (Goran *et al.* 1998)	40 M & 35 F (4-7 yeas)	4 years	Indirect calorimetry & DLW technique	Measured height & weight; DXA	No association between energy expenditure and change in fat mass	Parental fatness	0
USA (Figueroa-Colon *et al.* 2000)	47 F (7.5±1.1 years)	1.6±0.4 & 2.7-±0.6 years	Indirect calorimetry	DXA	At first f/up, baseline energy expenditure (adjusted for fat free mass) was inversely associated with change in %BF. At second f/up, energy expenditure was not associated with change in total body fat.	Age, body fat at baseline, parental body fat, sleep energy expenditure, f/up time	?

M: Male; F: Female; PA: physical activity; SB: sedentary behaviour; DLW: doubly-labeled water; DXA: dual x-ray absorptiometry; %BF: percent body fat; BMI: body mass index
* Overall effect of PA on adiposity: + Positive effect, 0 No association, - Negative effect, ? Inconclusive

Table 2: Self-reported physical activity & adiposity in childhood: a summary of prospective studies

Study	N, Sex (Age at Baseline)	Follow-Up (f/up)	Measure of PA/SB	Measure of Adiposity	Significant Findings	Adjustments	Overall Effect*	
							PA	**SB**
US Add Health (Gordon-Larsen *et al.* 2002)	6,288 M & 6,471 F (12-22 years)	1 year	Frequency of participation in moderate & vigorous PA; past week hrs spent TV & video viewing & computer use	Measured height & weight (BMI)	MV PA associated with decreased odds of obesity in both M & F; high TV viewing associated with increased odds of obesity in both M & F	Age, maternal education, family income, presence of moth, urban residence, smoking, region	-	+
US Growing Up Today study (Berkey *et al.* 2003)	5,120 M & 6,767 F (10-15 years)	1 year	Hours per week in 17 sports & activities over the past year; gym or PE classes per week; hrs/day of TV viewing	Self-reported height & weight (BMI)	M: ↑ PA was associated with ↓ BMI in owt boys F: ↑ PA was associated with ↓ BMI; ↑ inactivity was associated with ↑ BMI	Race/ethnic group, energy intake, growth, menstrual history, age, Tanner stage, baseline BMI	? ?	0 +
US Growing Up Today study (Berkey *et al.* 2000)	4,620 M & 6,149 F (9-14 years)	1 year	Hours per week in 17 sports & activities over the past year; gym or PE classes per week; hrs/day of TV viewing	Self-reported height & weight (BMI)	M: Non-school & school PA was not associated with change in BMI; TV viewing was positively associated with change in BMI F: Non-school PA was inversely associated with change in BMI; TV viewing was positively associated with change in BMI	Diet, PA, TV viewing, race, menarche history, annual height growth, baseline BMI, age & Tanner stage	0 -	+ +

Study	N, Sex (Age at Baseline)	Follow-Up (f/up)	Measure of PA/SB	Measure of Adiposity	Significant Findings	Adjustments	Overall Effect*	
							PA	SB
NHLBI NGHS study (Kimm *et al.* 2001)	2,379 F (9-10 years)	10 years	3-day PA diary	Measured height & weight; triceps, suprailiac & subscapular skinfolds	PA not significantly associated with change in adiposity	Race, age, pubertal stage, energy intake	0	N/A
Canada (O'Loughlin *et al.* 2000)	2,318 M & F at first f/up, 633 M & F at second f/up (9-12 years)	1 & 2 years	Past week frequency of 25 activities; school sports team participation; non-school sports /activities; TV viewing & video game usage	Measured height & weight (BMI)	M: No association between PA & weight gain at first f/up, but at second f/up those least active at baseline had ↑ odds of weight gain; no association with TV viewing or computer use	Baseline BMI, PA, SB, age at baseline, grade, year of cohort, school	?	0
					F: Non-school sport & video games associated with ↑ odds of weight gain at first f/up, but not second; no association with TV viewing		?	?
USA (Kimm *et al.* 2005)	2,287 F (9-10 years)	9-10 years	Past 12 months extracurricular sports &/or PA	Measured height & weight (BMI)	Decline in PA was associated with ↑ in BMI & skinfolds	Race, age, age at menarche, energy intake, childbirth, smoking	-	N/A

Study	N, Sex (Age at Baseline)	Follow-Up (f/up)	Measure of PA/SB	Measure of Adiposity	Significant Findings	Adjustments	Overall Effect*	
							PA	SB
US CTLS (Kaur *et al.* 2003)	1,149 M & 1,074 F (12-17 years)	3 years	Average hours of TV watched per day	Self-reported height & weight (BMI)	Higher TV viewing associated with higher BMI; >2 hrs TV viewing at baseline associated with increased odds of owt (OR: 2.2, 95% CI: 1.4-3.6)	Ethnicity, baseline BMI	N/A	+
France - FLVS II (Kettaneh *et al.* 2005)	436 M & F (8-18 years)	2 years	Duration of LTPA & weekly hrs spent in TV viewing/video games in past year	Measured height & weight (BMI); four skinfold measures; WC	M: No association between PA or TV viewing & adiposity F: Higher levels of moderate PA associated with higher adiposity measures; no association with TV; ↓ moderate PA associated with highest adiposity, compared to sustained or ↑ PA	Adiposity, Tanner stage, age	0 ?	0 0
Wales (Elgar *et al.* 2005)	335 M & F (12.3 years)	4 years	HBSC tool - frequency of PA of ≥60 minutes duration; hours of TV (incl. video)	Measured height & weight (BMI)	PA influenced change in body mass; TV viewing influence body mass	Sex, age, number of parents, family size	?	?
US (Robinson *et al.* 1993)	279 M & F (12-13 years	2 years	Hrs TV viewing after school	Measured height & weight (BMI); triceps skinfold	No association between TV viewing & BMI or triceps skinfold in M or F	Age, race, parent education, parent fatness	0	0

Study	N, Sex (Age at Baseline)	Follow-Up (f/up)	Measure of PA/SB	Measure of Adiposity	Significant Findings	Adjustments	Overall Effect*	
							PA	SB
Italy (Maffeis *et al.* 1998)	112 (7-9 years)	4 years	Parental report of weekly sport & programmed exercise; daily hrs of TV	Measured height & weight (BMI)	PA & TV viewing not associated with BMI	Age, gender, energy intake, nutrient intake, parental BMI, TV viewing	0	0
Belgian Boys Study (Beunen *et al.* 1992)	64 M (12-19 years)	6 years	Parental report of weekly participation in past year sport	Measured height & weight; 4 skinfolds	M: No difference in adiposity between active & non-active boys	Nil	0	N/A
Australia (Bogaert *et al.* 2003)	29 M & 30 F (6-9 years)	1 year	Parental report – 3-day PA diary & hours TV viewing per week	Measured height & weight (BMI); BIA	Percent time spent in low-intensity PA correlated with %BF in all children ($r=0.28$, $P<0.05$), but not when stratified by sex. No association between TV viewing & adiposity	Nil	?	0

PA: physical activity; MVPA: moderate to vigorous physical activity; LTPA: leisure time physical activity; SB: sedentary behaviour (TV viewing, computer usage, video games); WC: waist circumference
NHLBI: National Heart, Lung & Blood Institute; NGHS: Growth & Health Study; Add Health: National Longitudinal Study of Adolescent Health; CTLS: California Teen Longitudinal Survey; FLVS II: Fleurbaix-Laventie Ville Sante II study
* Overall effect of PA & SB on adiposity: + Positive effect, 0 No association, - Negative effect, ? Inconclusive

Table 3: Objectively measured physical activity & adiposity in childhood: a summary of cross-sectional studies

Study	N, Sex (Age at Baseline)	Measure of PA/SB	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect*
US, Australia & Sweden (Vincent *et al.* 2003)	959 M & 995 F (6-12 years)	Yamax pedometers (MLS-2000) (4 weekdays)	Measured height & weight (BMI)	IOTF cutpoints	M: Few significant correlations observed F: Few significant correlations observed	Nil	0 0
Nova Scotia (Thompson *et al.* 2005)	792 M & 861 F (Grades 3, 7 & 11)	Actigraph accelerometer (7 days)	Measured height & weight (BMI)	At risk of owt≥85th but <95th percentile; Owt≥95th percentile (CDC growth charts)	No significant difference in average total daily mins or daily minutes of moderate, hard or very hard PA between groups for both boys & girls	Nil	0
Sweden (Raustorp *et al.* 2004)	457 M & 435 F (7-14 years)	Yamax Digiwalker pedometers (SW-200) (4 days)	Measured height & weight (BMI)	IOTF cutpoints	M: No significant correlation between daily steps & BMI F: No significant correlation between daily steps & BMI	Nil	0 0
USA (Treuth *et al.* 2005)	99 M & 130 F	Actiwatch accelerometer (6 days)	Measured height & weight (BMI); fat mass, fat-free mass & %BF from BIA	At risk/owt≥85th (CDC growth charts)	M: No significant difference in daily counts between normal & owt boys F: Light, but not moderate or vigorous, PA & sedentary behaviour associated with fat mass & %BF in all girls & with BMI in middle & high school girls	Stratified by school level & sex	0 -

Study	N, Sex (Age at Baseline)	Measure of PA/SB	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect*
Portugal (Mota *et al.* 2002)	64 M & 93 F (8-15 years)	CSA accelerometer (3 days)	Measured height & weight (BMI)	IOTF cutpoints	M: No significant difference in PA between healthy weight & owt F: Healthy weight girls had higher mean PA counts & mins in MVPA	Nil	0 -
UK (Page *et al.* 1994)	68 M & 65 F (9-11 years)	Accelerometer (7 days)	Measured height & weight (BMI)	Obese: >99th BMI percentile	Obese children were significantly less active & spent less time in MVPA than non-obese children	Nil	-
Australia (Ball *et al.* 2001)	52 M & 54 F (6-9 years)	DLW	Measured height & weight; fat & fat-free mass from DLW	Measures treated as continuous variables	M: Activity EE & PAL were correlated with BMI, fat mass & %BF F: Activity EE & PAL were not correlated with any anthropometric measure	Nil	- 0
Northern Ireland (Rennie *et al.* 2005)	100 M & F (6-8 years)	DLW & heart rate monitoring	Isotopic dilution	Measures treated as continuous variables	↑ fat free mass was associated with ↑ activity EE & PAL	Sex, fat mass index	-
New Zealand (Rush *et al.* 2003)	40 M & 39 F (5-14 years)	DLW	Measured height & weight & BIA	Measures treated as continuous variables	M: PAL & activity EE were inversely correlated with %BF (r=-0.43 & -0.52) F: No significant correlation	Nil	- 0

Study	N, Sex (Age at Baseline)	Measure of PA/SB	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect*
Australia (Abbott *et al.* 2004)	23 M & 24 F (5-10 years)	DLW & four days accelerometry (Tritrac)	Measured height & weight (BMI); %BF from DLW	Measures treated as continuous variables	PAL from DLW was significantly correlated with %BF (r=-0.43) & BMI (r=-0.45); accelerometers: vigorous & hard, but not moderate, PA were correlated with %BF (r=-0.44 & -0.39)	Nil	-
Germany (Grund *et al.* 2000)	24 M & 16 F (4-11 years)	Indirect calorimetry; heart rate monitoring	Measured height & weight; five skinfolds; BIA	Measures treated as continuous variables	Fat free mass was correlated with total EE (r=0.61)	Age, gender, fat mass	-
Wales (Rowlands *et al.* 1999)	17 M & 17 F (8-10 yrs)	Tritrac accelerometer & Yamax Digiwalker pedometer (DW-200) for 3-6 days; heart rate (HR) telemetry (1 day)	Measured height & weight (BMI); 7 skinfold thicknesses	Measures treated as continuous variables	Correlations between PA & sum of 7 skinfolds were low to moderate, but not statistically significant when stratified by sex	Nil	0

IOTF: international obesity taskforce; WC: waist circumference; HC: hip circumference; %BF: percent body fat; HR: heart rate; DLW: doubly labeled water; PAL: physical activity level (total energy expenditure/resting metabolic rate); MVPA: moderate to vigorous physical activity; EE: energy expenditure; BIA: bioelectrical impedance analysis
SWEDES: Stockholm Weight Development Study
* Overall effect of PA & SB on adiposity: + Positive effect, 0 No association, - Negative effect, ? Inconclusive

Table 4: Self-reported physical activity & adiposity in childhood: a summary of cross-sectional studies

Study	N, Sex (Age at Baseline)	Measure of PA/SB	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect*	
							PA	SB
34-Country HBSC (Janssen *et al.* 2005)	137,593 M & F (10-16 years)	Frequency of PA of ≥60 minutes duration; hours of TV (including video) & computer usage	Self-reported height & weight (BMI)	IOTF cutpoints	M & F: PA & BMI were inversely related in 88% of countries; TV viewing & BMI were positively related in 65% of countries; computer use & BMI not related	Age, gender, presently trying to lose weight, diet & PA	-	+
US YRBS 1999 (Eisenmann *et al.* 2002)	15,143 M & F (14-18 years)	Past week frequency of vigorous PA, moderate PA; & past year no. of sports played	Self-reported height & weight (BMI)	Owt = BMI≥ 85th percentile	M: Lower frequency of PA associated with ↑ odds of owt (OR: 1.37); lower frequency of TV viewing associated with ↑ odds of owt (OR: 0.58-0.78)	Nil	-	+
					F: No difference in odds of owt with differing levels of moderate or vigorous PA; lower frequency of TV viewing associated with ↑ odds of owt (OR: 0.61)		0	+
US YRBS 1999 (Levin *et al.* 2003)	6,451 M & 6,844 F (Grades 9-12)	Past week frequency of vigorous PA, moderate PA, strength training & PE class; & past year no. of sports played	Self-reported height & weight (BMI)	At risk of owt = BMI≥ 85th percentile; Owt = BMI ≥95th percentile	M: At risk of owt or owt subjects less likely to participate in sport; owt not associated with vigorous PA, moderate PA, strength training or PE class participation	Grade level, ethnicity	?	N/A
					F: Owt girls less likely to participate in moderate PA & strength training. Owt not associated with vigorous PA, PE class or sports participation		?	N/A

Study	N, Sex (Age at Baseline)	Measure of PA/SB	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect*	
							PA	SB
Canada – NLSCY (Tremblay *et al.* 2003)	7,216 M & F (9-11 years)	Parental report of outside of school sports; unorganised sports or PA; computer or video game usage; hours of TV viewing/week	Parental self-report	IOTF cutpoints	Participation in organised & non-organised sport associated with ↓ odds of owt & obesity; higher video & TV usage associated with ↑ risk of owt & obesity	Sex, age, number of parents, SES	-	+
Canadian HSBC (Janssen *et al.* 2004)	2,812 M & 3,078 F (11-16 years)	Frequency of PA of ≥60 minutes duration; hours of TV (including video) & computer usage	Self-reported height & weight (BMI)	IOTF cutpoints	M: ↑ frequency of PA associated with ↓ odds of owt or obesity;↑ duration of TV viewing associated with ↑ odds of owt & obesity; no association with computer use F: ↑ frequency of PA associated with ↓ odds of obesity;↑ duration of TV viewing associated with ↑ odds of owt & obesity; no association with computer use	Age, dietary variables, LTPA	- -	+ +
US NHANES III (Crespo *et al.* 2001)	1,994 M & 2,075 F (8-16 yrs)	Interview – weekly frequency of vigorous PA; past day hrs TV viewing	Measured height & weight (BMI)	Obese = BMI≥95th percentile	M: PA & obesity not associated; highest hrs TV ↑ odds of obesity (OR: 2.63 for ≥5hrs/day) F: PA & obesity not associated; 3hrs/day or more TV ↑ odds of obesity (OR: 2.53-3.85)	Age, race/ ethnicity, family income, energy intake, PA	0 0	+ +

Study	N, Sex (Age at Baseline)	Measure of PA/SB	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect*	
							PA	SB
US NHANES III (Andersen *et al.* 1998)	1,985 M & 2,071 F (8-16 years)	Interview – weekly frequency of vigorous PA; past day hrs TV viewing	Measured height & weight (BMI); supscapular & suprailiac skinfolds	Measures treated as continuous variables	M: ↑ frequency of vigorous PA associated with higher BMI but not skinfolds; ↑ TV associated with ↑ BMI & skinfolds F: No association seen between PA & BMI or skinfolds; ↑ TV associated with ↑ BMI & skinfolds	Tanner score	? 0	+ +
Belgium (Deforche *et al.* 2003)	1,646 M & 1,560 F (12-18 years)	Sport & leisure time PA	Measured height & weight (BMI); five skinfold thicknesses	Measures treated as continuous variables	M: No difference in sport or leisure time PA between obese & non-obese F: No difference in sport or leisure time PA between obese & non-obese	Stratified by age	0 0	N/A
HOYVS (Wake *et al.* 2003)	1,445 M & 1,417 F (5-13 years)	Parental report of hours of TV viewing time & video game/computer use	Measured height & weight (BMI z-scores)	IOTF cutpoints	Greater TV viewing associated with slightly ↑ odds of owt & obesity, but not in highest group of TV viewing; no association with video game/computer usage	Maternal BMI & education, no. of children in family, food intake, organised exercise & general activity	N/A	?

Study	N, Sex (Age at Baseline)	Measure of PA/SB	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect*	
							PA	SB
US NHANES III (Dowda *et al.* 2001)	1,336 M & 1,455 F (8-16 years)	Interview – weekly frequency of vigorous PA; no. of sports teams & exercise programs in past year; past day hrs TV viewing	Measured height & weight (BMI)	Owt = BMI ≥85th percentile	M: Participation in sports/exercise, but not vigorous PA or TV viewing, associated with ↓ risk of owt F: Participation in sports/exercise associated with ↓ risk of owt in older girls; vigorous PA not associated with risk of owt; ≥4hrs TV associated with ↑ odds of owt	Age, race/ethnicity, PA, parental wt, family size, poverty	? ?	0 +
US CHIC (McMurray *et al.* 2000)	1,149 M & 1,240 F (10-16 yrs)	Frequency of participation in 32 common activities; hours of TV viewing & video games	Measured height & weight (BMI); tricep & subscapular skinfolds	Owt = BMI≥ 85th percentile	M: Reduced odds of owt with ↑ PA (OR: 0.54-0.65); no association with TV viewing or video games F: No association between owt & PA, TV viewing or video games	Nil	- 0	0 0
Young Finns (Aaron *et al.* 1995; Raitakari *et al.* 1997)	1,114 M & 1,244 F (9-24 years)	Frequency & intensity of PA outside of school	Measured height & weight (BMI); subscapular skinfolds	N/A	M: Higher PA associated with lower BMI & subscapular thickness F: Higher PA associated with lower subscapular thickness but not BMI	Nil	- ?	N/A N/A
Singapore Youth Coronary Risk & PA Study (Schmidt *et al.* 1997)	784 M & 897 F (6-18 years)	Frequency of hard PA, easy PA; hrs multimedia use; yearly no. of sports (interviews in PS, self-administered in SS)	%BF derived from 8 skinfolds	Measures treated as continuous variables	PA inversely associated with %BF in all children	Nil	-	N/A

Study	N, Sex (Age at Baseline)	Measure of PA/SB	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect*	
							PA	SB
Belgian Luxembourg Child Study II (Guillaume *et al.* 1997)	1,028 M & F (6-12 years)	Duration of two preferred leisure time sports; self-reported weekly duration & frequency of TV viewing	Measured height, weight, WC, HC; triceps & subscapular skinfolds	Measures treated as continuous variables	M: Sports activity inversely associated with skinfold thicknesses; TV viewing positively associated with BMI & triceps skinfold thickness	Nil	-	+
					F: No association seen between PA or TV viewing & BMI or skinfold thicknesses		0	0
Nth Ireland Young Hearts Project (Boreham *et al.* 1997)	503 M & 512 F (12 & 15 years)	PA (active transport, recess & lunch, school-based activities); weekly sports participation outside of school sports	Measured height & weight (BMI); %BF derived from 4 skinfolds	Measures treated as continuous variables	M: No association seen between PA & % body fat	Nil	0	N/A
					F: Sports participation negatively correlated with % body fat (r=-0.10) at 15 years		-	N/A
Oslo Youth Study (Tell *et al.* 1988)	413 M & 372 F (10-15 years)	Frequency of vigorous LTPA in the past week	Measured height & weight (BMI); triceps thickness	Measures treated as continuous variables	M: PA frequency associated with BMI & triceps thickness	Sexual maturity	-	N/A
					F: No association seen between PA & BMI or triceps thickness		0	N/A
US NLSY (Gortmaker *et al.* 1996)	746 M & F (10-15 years)	Parental & self-report of TV viewing on a typical weekday & weekend day	70-80% measured height & weight; rest were parent reported	Overweight = BMI>85^{th} percentile	Higher levels of TV viewing associated with ↑ risk of obesity (OR: 2.84-5.26)	Household income, mother's education & age, race	N/A	+

Study	N, Sex (Age at Baseline)	Measure of PA/SB	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect*	
							PA	SB
Singapore Youth Coronary Risk & PA Study (Schmidt *et al.* 1998)	705 M & F (8-18 years)	Frequency of hard PA, easy PA; hrs multimedia use; yearly no. of sports (interview -administered in PS, self-administered in SS)	Measured height & weight (BMI); %BF derived from 8 skinfolds	Measures treated as continuous variables	M: Days of hard & easy exercise & PA grouping negatively correlated with % body fat (r=-0.13 for all PA measures)	Nil	?	0
					F: Days of hard exercise, PA grouping & no. of sports played negatively correlated with BMI & % body fat (r=-0.15 to -0.27)		-	0

PA: physical activity; SB: sedentary behaviour (TV viewing, computer usage, video games); Owt: overweight; IOTF: IOTF: international obesity taskforce; PS: primary schools; SS: secondary schools; BMI: body mass index; %BF: percent body fat; YRBS: youth risk behaviour survey; HSBC: healthy behaviour in school-aged children survey; NHANES: national health and nutrition examination system; CHIC: cardiovascular health in children; NLSY: National Longitudinal Survey of Labor Market Experience, Youth Cohort; N/A: not applicable
* Overall effect of PA & SB on adiposity: + Positive effect, 0 No association, - Negative effect, ? Inconclusive

A Case for Treating "Missing" Values as Physical Inactivity

Background

When analysing physical activity data from Question 2 of the student questionnaire completed as part of the 1985 Australian Schools Health and Fitness Survey (ASHFS), it was apparent that a non-ignorable amount of "missing" values were present. However, it was also apparent that there were no zero values in the dataset, suggesting that "missing" values were likely to represent non-participation in physical activity. Whilst the number of "missing" values was of concern, it is possible that data collectors instructed participants to leave questions blank if they did not participate in an activity, given the large amount of questions involved in the survey, especially for children as young as 9 years. An interview protocol detailing how data collectors were to instruct participants on completing Question 2 was unable to be located. An alternate explanation for the lack of zero values and large amount of "missing" values is that zero values may have been left blank during the data entry process. Again, a data entry protocol was unable to be located so this possibility also cannot be confirmed. To determine whether it was appropriate to treat "missing" items as non-participation in physical activity the patterns of missingness in the dataset were investigated and cross-validated against responses to other related questions.

Assessment of "Missing" Values

Assessment of Incomplete Questionnaires

It was plausible that missing data in Question 2 were a result of incompleteness of questionnaires, which should be excluded from analyses. To investigate this possibility, an assessment of the number of missing values in the entire questionnaire was made. This was done by summing the number of missing values in the questionnaire for each participant to create a missing value frequency count. For Questions 16, 22, 25 and 26, only the first component of each question was included (for example, 16a and 22a were included but 16b and 22b were not). For question 2, the frequency, but not duration or effort, of cycling and walking to school and school physical education was included in the missing values count, as was whether a participant had indicated participation in school sport or other activity. Out of a possible 44 missing values, 97.8% of the sample had 30 or fewer missing values (Table 1). The remaining 2.2% of participants had more than 30 missing values and were deemed to have not sufficiently completed the questionnaire; these participants were excluded from further analyses.

Table 5: Frequency of missing values throughout the entire student questionnaire

Missing Count	Frequency	%	Cumulative %
0	91	1.4	1.4
1	1,182	18.0	19.4
2	2,369	36.1	55.5
3	1,801	27.5	83.0
4	758	11.6	94.5
5	152	2.3	96.9
6	41	0.6	97.5
7	7	0.1	97.6
8	5	0.1	97.7
10	1	0.02	97.7
12	1	0.02	97.7
13	2	0.03	97.7
15	1	0.02	97.7
16	1	0.02	97.8
26	1	0.02	97.8
29	1	0.02	97.8
31	145	2.2	100.0
Total	6,559	100.00	

Assessment of Incomplete Data in Question 2

The number and proportion of children reporting the frequency and duration of physical activity is presented in Table 2. The findings suggest that if participants provided information on one dimension of an activity (i.e. frequency or duration), they were likely to have also provided information on the other component of that activity.

Table 6: Number & proportion of children reporting frequency (F) or duration (D) of physical activity in the ASHFS 1985 (N=6,414)

Domain of PA	Frequency	Duration	F & D
	n	n	n (%)
Cycling	1,245	1,247	1,242 (19.4)
Walking	2,644	2,638	2,629 (41.0)
School PE	4,703	4,700	4,686 (73.1)
School Sport			
Sport 1	3,781	3,791	3,751 (58.5)
Sport 2	642	653	639 (10.0)
Other PA			
Other 1	4,791	4,802	4,756 (74.2)
Other 2	2,561	2,577	2,547 (39.7)
Other 3	1,002	1,011	997 (15.5)
Other 4	97	308	304 (4.7)

The number of physical activity domains completed by participants is presented in Table 3. For the purposes of this thesis a complete domain included information on both frequency and duration in regards to either walking to/from school, cycling to/from school, school physical education, school sport or other activities (five possible domains). The findings suggest that most participants completed between one and four domains of physical activity, and only a small proportion appeared to be very active (1.5%) or very inactive (0.3%).

Table 7: Number of physical activity domains (frequency & duration) completed by children in the ASHFS 1985

Number of Domains Completed	n	%
Q2 Not Attempted	103	1.6
0 domains	18	0.3
1 domain	723	11.3
2 domains	1,799	28.1
3 domains	2,438	38.0
4 domains	1,236	19.3
5 domains	97	1.5
Total	6,414	100.0

The number of physical activity domains completed by participants was consistent across sex and school level (Table 4). This table suggests that there were no obvious subgroups where "missing" values were more common than would be expected.

Table 8: Number of physical activity domains (frequency & duration) completed by children in the ASHFS 1985, by sex & school level

School Level & Domain of PA Completed	Males		Females	
	n	%	n	%
Primary	(N=1,646)		(n=1,662)	
Q2 Not Attempted	13	0.8	28	1.7
0	6	0.4	5	0.3
1	152	9.2	172	10.4
2	443	26.9	460	27.7
3	623	37.9	634	38.2
4	373	22.7	333	20.0
5	36	2.2	30	1.8
Secondary	(N=1,610)		(n=1,496)	
Q2 Not Attempted	28	1.7	34	2.3
0	5	0.3	2	0.1
1	187	11.6	212	14.2
2	434	27.0	462	30.9
3	621	38.6	560	37.4
4	314	19.5	216	14.4
5	21	1.3	10	0.7

While these findings suggest that "missing" values infer non-participation in physical activity, 103 participants did not provide any information in Question 2. The characteristics of these participants required further investigation and are presented in Table 5, compared to those participants who provided some information in Question 2. The table suggests that females, older children, those from lower socioeconomic groups and those who were overweight were less likely to provide information at Question 2. It is well-documented in the literature that these groups participate in less physical activity, providing further support for treating "missing" values as non-participation. There was little difference by school type and state, suggesting that school or state-based policies were not responsible for "missing" values.

Table 9: Descriptive characteristics of participants who did & did not provide information at Question 2 in the ASHFS 1985

Participant Characteristic	**No Information Provided at Q2** (n=103)		**Information Provided at Q2** (n=6,311)	
	n	**%**	**n**	**%**
Sex				
Male	41	39.8	3,215	50.9
Female	62	60.2	3,096	49.1
School Level				
Primary	41	39.8	3,267	51.8
Secondary	62	60.2	3,044	48.2
School Type				
Government	81	78.6	4,657	73.8
Catholic	18	17.5	1,314	20.8
Independent	4	3.9	340	5.4
SES Quartile				
Low	6	5.8	576	9.1
Low-Med	49	47.6	2,378	37.7
Med-High	23	22.3	1,777	28.2
High	24	23.3	1,466	23.2
Missing	1	1.0	114	1.8
Weight Status				
Healthy Weight	85	82.5	5,564	88.2
Overweight	18	17.5	742	11.8
Missing	0	0.0	5	0.1
State/Territory				
ACT	3	2.9	130	2.1
NSW	35	34.0	2,147	34.0
Victoria	24	23.3	1,598	25.3
Queensland	21	20.4	1,106	17.5
South Australia	10	9.7	544	8.6
Western Australia	6	5.8	529	8.4
Tasmania	1	1.0	125	2.0
Northern Territory	3	2.9	132	2.1

The responses to Questions 3-9 for those participants who did and did not provide information at Question 2 were examined to determine whether these children were consistently less active (Table 6). A larger proportion of participants who did not provide information at Question 2 indicated that they were usually more active, that they did not have or did not do school PE, that they did not do school sport, and that they did not enjoy physical activity, compared to those who provided information at Question 2. Similarly, a smaller proportion of participants who did not provide information at Question 2 indicated that they exercised 3-4 times per week at an intensity that made them huff and puff, that they played sports or ran around at recess and lunch time, and that they enjoyed PE or school sport a lot, compared to those who did provide information at Question 2. The responses to Questions 3-9 of children who did not provide information at Question 2 suggests that these children were less inclined to participate in and enjoy physical activity than those who did provide information at Question 2. These data provide additional support to the notion that "missing" values infer non-participation in the physical activities listed in Question 2.

Table 10: Responses to Questions 3 to 9 for those who did & did not attempt Question 2 in the ASHFS 1985

	No Information Provided at Q2 (n=103)		**Information Provided at Q2** (n=6,311)	
Question/Response Categories	**n**	**%**	**n**	**%**
Q3: Is your answer to the last question (question 2) typical of your exercise pattern in the past month?				
I am usually more active	57	55.3	2,160	34.2
The same as usual	30	29.1	3,825	60.6
I am usually less active	4	3.9	277	4.4
Missing	12	11.7	49	0.8
Q4: In most weeks do you get exercise/ activity 3 or 4 times which makes you huff & puff & lasts at least 30 minutes each time?				
Yes	32	30.4	2,647	41.9
No	65	63.7	3,602	57.1
Missing	6	5.9	62	1.0
Q5: What do you usually do at recess (usually means 3 or more days/week)				
Sit & talk to friends	24	23.5	1,495	23.7
Walk around the school	41	40.2	1,571	24.9
Run around playing sports/games	31	29.4	2,970	47.1
Read/study for the next classes	0	0.0	40	0.6
Nothing much	4	3.9	203	3.2
Other	0	0.0	15	0.2
Missing	3	2.9	17	0.3
Q6: What do you usually do at lunch time (usually means 3 or more days/week)				
Sit & talk to friends	21	20.6	951	15.1
Walk around the school	36	35.3	1,435	22.7
Ride or walk home for lunch	0	0.0	126	2.0
Train for school sports teams	6	5.9	816	12.9
Play sport/games on the oval or in the school grounds	32	31.4	2,869	45.5
Study or do homework	3	2.9	71	1.1
Other	1	1.0	31	0.5
Missing	4	3.9	12	0.2
Q7: Do you enjoy school physical education classes?				
Very much	32	31.1	2,462	39.0
Quite a lot	21	20.4	1,521	24.1
Sometimes	26	25.2	1,636	25.9
Not much	3	2.9	204	3.2
Not at all	3	2.9	100	1.6
We don't have school PE	6	5.8	179	2.8
I don't do PE	10	9.7	194	3.1
Missing	2	1.9	15	0.2

	No Information Provided at Q2 (n=103)		Information Provided at Q2 (n=6,311)	
Question/Response Categories	**n**	**%**	**n**	**%**
Q8: Do you enjoy school sports?				
Very much	44	42.7	3,132	49.6
Quite a lot	13	12.6	1,462	23.2
Sometimes	23	22.3	1,130	17.9
Not much	6	5.8	164	2.6
Not at all	1	1.0	63	1.0
We don't have school sports	1	1.0	64	1.0
I don't do sport	12	11.7	281	4.5
Missing	3	2.9	15	0.2
Q9: Do you enjoy physical activity?				
Yes	88	85.4	6,063	96.1
No	11	10.7	195	3.1
Missing	4	3.9	53	0.8

Conclusions

The findings from this investigation suggest that treating the "missing" values in Question 2 as non-participation in these physical activities is reasonable and appropriate. While initially the non-ignorable amount of "missing" values was of concern, after a thorough investigation of the characteristics and behaviours of these participants it would appear that these data represented non-participation in the physical activities listed. This investigation highlights the importance of documenting data collection and management protocols when conducting epidemiological studies, of constructing questionnaires that allow non-participation in physical activity to be easily identified, and of the many difficulties encountered when analysing data from an historical dataset.

Appendix 13c

Chapter 3: Additional Data Tables

Table 11: Mean (standard deviation) weight (kg) & height (cm) for children aged 9-15 years in the ASHFS 1985, by sex & age

Measure & Age (years)	Boys n	Boys Mean (SD)	Girls n	Girls Mean (SD)	p
Weight (kg)					
9	482	31.6 (5.7)	488	31.6 (5.8)	0.99
10	493	34.3 (5.7)	497	34.8 (6.6)	0.26
11	488	38.9 (7.8)	484	39.7 (8.3)	0.12
12	494	42.9 (9.4)	489	44.2 (8.5)	0.02
13	466	49.1 (10.2)	438	49.6 (8.5)	0.43
14	467	54.2 (10.0)	408	52.4 (8.0)	0.002
15	451	59.8 (9.9)	413	55.3 (8.6)	<0.01
Overall	3,341	44.2 (12.8)	3,217	43.4 (11.4)	0.009
Height (cm)					
9	482	136.0 (5.9)	488	135.3 (6.4)	0.07
10	492	140.8 (6.1)	497	140.7 (6.5)	0.89
11	488	146.0 (7.1)	484	147.2 (7.6)	0.009
12	494	151.2 (7.9)	489	153.0 (7.0)	<0.01
13	466	159.0 (8.7)	437	157.7 (6.8)	0.01
14	467	164.8 (8.9)	408	160.7 (6.3)	<0.01
15	450	170.3 (7.8)	413	161.7 (5.9)	<0.01
Overall	3,339	152.3 (13.9)	3,216	150.3 (11.5)	<0.01

Table 12: Average BMI (kg/m^2) of children aged 9-15 years in the ASHFS 1985, by sex & age

Age (years)	Boys n	Boys Mean (SD)	Girls n	Girls Mean (SD)	p
9	482	17.0 (2.3)	488	17.0 (2.3)	0.24
10	492	17.3 (2.1)	497	17.3 (2.1)	0.19
11	487	18.1 (2.6)	484	18.1 (2.6)	0.79
12	494	18.6 (2.9)	489	18.6 (2.9)	0.39
13	466	19.3 (2.9)	437	19.3 (2.9)	0.002
14	467	19.9 (2.7)	408	19.9 (2.7)	0.02
15	450	20.5 (2.6)	413	20.5 (2.6)	0.01
Overall	3,338	18.6 (2.9)	3,216	18.6 (2.9)	<0.01

Table 13: Average waist circumference (cm) of children aged 9-15 years in the ASHFS 1985, by sex & age

Age (years)	Boys		Girls		p
	n	Mean (SD)	n	Mean (SD)	
9	482	60.0 (6.0)	487	59.1 (6.3)	0.02
10	493	61.5 (5.9)	497	60.7 (6.9)	0.06
11	488	64.8 (7.8)	484	63.2 (7.5)	0.01
12	494	66.9 (8.5)	489	64.8 (7.3)	<0.01
13	466	69.8 (7.6)	438	67.0 (6.9)	<0.01
14	467	71.5 (6.9)	406	68.3 (6.7)	<0.01
15	451	73.3 (7.5)	412	69.9 (7.7)	<0.01
Overall	3,341	66.7 (8.6)	3,213	64.5 (7.9)	<0.01

Table 14: Mean (standard deviation) PWC170 (W/kglbm) according to intensity of physical activity at recess & lunchtime by age and sex in the ASHFS 1985, by sex & age

Age	Sex	Recess/Lunchtime Activity (Mean, SD)				p
		Low	Low-Moderate	Moderate-High	High	
9	M	2.7 (0.6)	2.8 (0.8)	2.9 (0.7)	3.0 (0.6)	0.28 [b]
	F	2.2 (0.5)	2.5 (0.6)	2.3 (0.5)	2.4 (0.6)	0.07 [b]
12	M	2.9 (0.6)	3.0 (0.5)	2.8 (0.6)	3.0 (0.6)	<0.05 [b]
	F	2.7 (0.6)	2.5 (0.6)	2.5 (0.6)	2.6 (0.5)	0.26 [b]
15	M	3.2 (0.7)	3.3 (0.6)	3.2 (0.7)	3.2 (0.9)	0.96 [a]
	F	2.3 (0.8)	2.4 (0.6)	2.5 (0.5)	2.6 (0.8)	<0.01 [a]
All	M	3.1 (0.7)	3.1 (0.6)	3.0 (0.7)	3.0 (0.7)	0.04 [b]
	F	2.4 (0.7)	2.5 (0.6)	2.4 (0.6)	2.5 (0.6)	0.70 [a]

[a] p-values derived from Kruskall-Wallis equality of populations rank test
[b] p-value derived from one-way ANOVA

Appendix 14a

Chapter 4: Literature Summary Tables

Table 15: Self-reported physical activity & adiposity in adulthood: a summary of prospective studies

Study	Sample	Follow-Up (f/up)	Measure of PA	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect *
USA (Kahn *et al.* 1997)	35,156 M & 40,808 F (50-74 years); NP sample	10 years	Average time in 10 moderate or vigorous activities in past year	Self-reported height & weight (BMI)	Treated as a continuous variable	M: ≥1 hr jogging/running or aerobics/ calisthenics & walking or gardening ≥4 hrs/week was associated with a ↓ in BMI F: ≥4 hr aerobics/calisthenics or walking & ≥1 hr/week gardening associated with a ↓ in BMI	Age, education, region, baseline BMI, marital status, calorie intake, smoking, meat & vegetable intake, alcohol & menopause, estrogen use & parity	? ?
Nurses' Health Study (Hu *et al.* 2003)	50, 277 F (36-71 years); NP sample	6 years	Average weekly duration of MVPA; walking pace; time sitting watching TV/VCR, at work, away from home, or driving	Self-reported height & weight (BMI)	Obese = BMI≥30kg/m^2	Brisk walking was associated with a ↓ risk of obesity; TV viewing & sitting at work associated with ↑ risk of obesity	Age, smoking, exercise levels, dietary factors	-

Study	Sample	Follow-Up (f/up)	Measure of PA	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect *
Health Prof. Follow-Up (Coakley *et al.* 1998)	19,478 M (40-75 years); NP sample	4 years	Average hours/ week in vigorous PA in past year; hours/week in TV/ VCR use	Self-reported height & weight (BMI)	Treated as a continuous variable	An ↑ in vigorous PA was associated with a ↓ in weight; a ↓ in vigorous PA was associated with an ↑ in weight; an ↑ in TV/VCR use was associated with an ↑ in weight	Smoking, blood pressure, cholesterol, dieting practices	-
Health Prof. Follow-Up (Ching *et al.* 1996)	17,795 M (41-78 years); NP sample	2 years	Average weekly time in 10 activities over past year; hrs of weekly TV viewing	Self-reported height & weight (BMI)	Owt: >85th percentile (NHANES II)	A trend was evident for ↓ risk of owt with ↑ PA at baseline; no association between TV viewing at baseline & risk of owt	Age, smoking, TV viewing/PA	?
USA (Koh-Banerjee *et al.* 2003)	16,587 M (40-75 years); NP sample	9 years	Average weekly time in 10 activities over past year; hrs of weekly TV viewing	Self-reported height & weight (BMI) & waist & hip circumference	Treated as continuous variables	↑ in PA was associated with a ↓ in WC, while a ↓ in PA was associated with ↑ WC; ↑ in TV viewing was associated with an ↑ in WC	Age, baseline WC, baseline BMI, calories, smoking, fibre intake, alcohol	-
The Tromso Study (Norway) (Thune *et al.* 1998)	5220 M & 5869 F (20-49 years); probability sample	7 years	LTPA (sedentary, moderate, hard, very hard)	Measured height & weight (BMI)	Treated as a continuous variable	M: Sustained hard/very hard PA associated with less wt gain F: Sustained hard/very hard PA associated with less wt gain	Age, smoking, coffee, fat intake, menopausal status (F only)	- -

Study	Sample	Follow-Up (f/up)	Measure of PA	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect *
HUNT-I & II (Norway) (Droyvold *et al.* 2004)	9357 F (20-49 years); probability sample	11 years	Frequency, intensity & duration of leisure time exercise	Measured height & weight (BMI)	Treated as a continuous variable	High LTPA at baseline associated with a smaller ↑ at in BMI f/up than low LTPA	Age, education, BMI at baseline	-
NHANES-I Follow-Up Study (USA) (Williamson *et al.* 1993)	3,515 M & 5,810 F (25-74 years); probability sample	10 years	Recreational PA (low, moderate, high)	Measured height & weight (BMI)	Treated as a continuous variable & categories of weight change	Baseline PA not associated with wt gain; sustained low PA or a ↓ in PA associated with wt gain	Non-recreational PA, smoking, drinking status, morbidity, baseline BMI & age, education, race & duration of f/up	?
HUNT-I & II (Droyvold *et al.* 2004)	8,305 M (20-69 years); probability sample	11 years	Frequency, intensity & duration of leisure time exercise	Measured height & weight (BMI)	Treated as a continuous variable	Active at baseline associated with ↓ BMI at f/up compared to inactive at baseline. No difference between low, moderate or high PA at baseline	Smoking, education, age, BMI	?
Copenhagen City Heart Study (Petersen *et al.* 2004)	2,626 M & 3,653 F (20-78 years); probability sample	15 years	Intensity of LTPA	Measured height and weight (BMI)	Obese = BMI≥30kg/m^2	M: No significant association between baseline LTPA & risk of obesity; NS trend for ↑ odds of obesity with higher PA F: No significant association between baseline LTPA & risk of obesity	Age, sex, BMI, work PA, education, smoking, alcohol, familial obesity	0 0

Study	Sample	Follow-Up (f/up)	Measure of PA	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect *
Finland (Haapanen *et al.* 1997)	2,564 M & 2,695 F (19-63 years); probability sample	10 years	LTPA (conditioning exercise, sports, recreation, household chores, active commuting); global PA; historical PA	Self-reported height & weight (BMI)	Body mass gain ≥5kg; BMI ≥26kg/m^2	M: No difference in odds of wt gain/high BMI according to baseline LTPA; becoming or remaining inactive associated with ↑ odds of wt gain/high BMI F: Vigorous PA once, but not twice, per week or no regular PA associated with ↑ odds of wt gain/high BMI; becoming or remaining inactive associated with ↑ odds of wt gain/high BMI	M: Age, perceived health status, smoking, SES F: Age, smoking	? ?
USA - Healthy Worker Project (French *et al.* 1994)	1,639 M & 1,913 F (27-48 years); NP worksite sample	2 years	Frequency of work & LTPA of at least 20 mins duration	Measured height and weight (BMI)	Treated as a continuous variable	Walking & high intensity PA associated with a ↓ in wt	Age, education, occupation, marital status, treatment group, smoking, baseline dieting history, history of wt control programs, dieting status, food intake, PA	-
CARDIA (Schmitz *et al.* 2000)	1,447 M & 1,323 F (18-30 years); probability sample	10 years	Sports & exercise participation in past 12 months (vigorous & moderate)	Measured height and weight (BMI)	Treated as a continuous variable	Inverse association between PA change & wt change. ↓ PA associated with greater wt gain than ↑ or maintained PA	Age, time, clinical centre, smoking, alcohol, education, parity, fat intake	-

Study	Sample	Follow-Up (f/up)	Measure of PA	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect *
China Health & Nutrition Survey (Paeratakul *et al.* 1998)	1,636 M & 1,848 F (20-45 years); probability sample	2 years	Occupational PA (sedentary, moderate, strenuous)	Measured height and weight (BMI)	Treated as a continuous variable	M: Change in PA not associated with change in BMI F: ↑ in PA associated with a significant ↓ in BMI	Fat intake, energy intake, age	0 -
Finland (Rissanen *et al.* 1991)	1,382 M & 1,280 F (25-64 years); probability sample	5 years	Frequency of LTPA	Measured height and weight (BMI)	Treated as a continuous variable & obese = BMI≥30kg/m^2	M: Relative risk of gaining ≥5kg was ↑ in those reporting occasional or rare PA at baseline F: Relative risk of gaining ≥5kg was ↑ in those reporting occasional or rare PA at baseline	Age, BMI, marital status, education, smoking, alcohol, coffee, health status, no. of childbirths between baseline & f/up (F only)	- -
USA Pound of Prevention (Sherwood *et al.* 2000)	218 M & 826 F (20-45 years); NP sample	3 years	Frequency of work & LTPA of at least 20 mins duration	Measured height and weight (BMI)	Treated as a continuous variable	M: High intensity PA at baseline, but not moderate PA, occupational PA or group sports, was associated with ↓ in body wt F: Moderate, high & occupational PA, but not group sports, associated with ↓ in body wt	Age, treatment group, smoking, baseline PA	? -

M: male; F: female; LTPA: leisure time physical activity; PA: physical activity; MVPA: moderate to vigorous intensity PA; BMI: body mass index; BIA: bioelectrical impedance analysis; %BF: percent body fat; ↓: decrease; ↑: increase
*Overall effect of PA on adiposity: + Positive effect, 0 No association, - Negative effect, ? Inconclusive

Table 16: Objectively measured physical activity & adiposity in adulthood: a summary of cross-sectional studies

Study	Sample	Measure of PA	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect*
Japan (Yoshioka *et al.* 2005)	400 M & 388 F (18-84 years); NP sample	Accelerometer	Measured height & weight (BMI)	Owt = BMI≥ 25kg/m^2; Obese = BMI≥30kg/m^2	MVPA was higher in healthy weight participants; odds of owt ↓ with ↑ levels of vigorous, but not moderate, PA	Age, gender, other PA	-
USA (Wyatt *et al.* 2005)	344 M & 386 F (mean= 47.2 years); random probability sample	Yamax pedometer (4 days incl. 1 weekend day)	Self-reported height & weight (BMI)	Owt = BMI≥ 25kg/m^2; Obese = BMI≥30kg/m^2	Obese, but not owt, participants took fewer steps per day than healthy wt participants ($p<0.01$)	Sex, age, marital status, income	-
Combination of 22 studies (Westerterp *et al.* 1997)	144 M & 146 F (18-49 years); info not available on sampling	DLW technique	%BF measured by hydrodensito-metry or with isotope dilution	Measure treated as a continuous variable	M: Higher PA was related to lower %BF F: No relationship between PA & %BF	Age	- 0
Canada (Chan *et al.* 2003)	24 M & 158 F (28-61 years); NP worksite sample	Yamax Digiwalker SW-200 pedometer (3 days)	Measured height & weight (BMI), waist circumference	Owt = BMI≥ 25kg/m^2; Obese = BMI≥30kg/m^2	M: Steps/day inversely correlated with BMI ($r=-0.40$) F: Steps/day inversely correlated with BMI ($r=-0.40$) & waist ($r=-0.43$)	Nil	-

Study	Sample	Measure of PA	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect*
China (Yao *et al.* 2003)	63 M & 67 F (35-49 years); NP sample	Accelerometer	Isotope dilution	Measure treated as a continuous variable	PA was significantly associated with %BF (partial r=-0.31)	Diet, restaurant food consumption, sex, smoking	-
USA (Tudor-Locke *et al.* 2001)	41 M & 68 F (17-79 years; mean 44.9±15.8 years); NP convenience sample	Yamax Digiwalker (DW-500) (21 days)	Measured height & weight (BMI); BIA	Owt = BMI≥ 25kg/m^2; Obese = BMI≥30kg/m^2	Steps/day significantly correlated with BMI (r=-0.30) & %BF (r=-0.27); steps/day were lower & BMI was higher in owt & obese subjects	Nil	-
UK (Cooper *et al.* 2000)	36 M & 48 F (18-64 years; mean 38.6±9.3); NP worksite sample	CSA accelerometer (7 days)	Measured height & weight (BMI)	Owt = BMI≥ 25kg/m^2; Obese = BMI≥30kg/m^2	No difference between normal weight & owt participants. Obese participants consistently less active than non-obese (BMI<30kg/ m$^{2)}$	Nil	-
USA (Thompson *et al.* 2004)	80 F (40-66 years); sampling method not specified	New Lifestyles Digiwalker (SW-200) (7 days)	Mesured height & weight (BMI), waist & hip circumference; air displacement plethysmography	Measures treated as continuous variables	Daily steps were significantly correlated with %BF (r=–0.71), WHR (r=-0.64), waist (r=-0.61), BMI (r=-0.42) & hip (r=-0.29)	Nil	-

Study	Sample	Measure of PA	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect*
USA (Hornbuckle *et al.* 2005)	69 F (40-62 years); NP convenience sample	New Lifestyles Digiwalker SW-200 (7 days)	Measured height, weight, waist & hip circumference; underwater weighing	Measures treated as continuous variables	Steps/day significantly correlated with all anthropometric variables (r=-0.23 to –0.43)	Age, energy intake	-
USA (Whitt *et al.* 2003)	55 F (25-55 years); NP convenience sample	Actigraph accelerometer & Accusplit pedometer (4 days)	Measured height & weight (BMI)	Owt = BMI≥ 25kg/m^2; Obese = BMI≥30kg/m^2	Healthy weight women did more steps & MVPA, participated in at least 30 mins PA more often, and participated in longer bouts of PA, than owt or obese women	Nil	-

M: male; F: female; LTPA: leisure time physical activity; PA: physical activity; MVPA: moderate to vigorous intensity PA; BMI: body mass index; BIA: bioelectrical impedance analysis; %BF: percent body fat; DLW: doubly labeled water; WHR: waist to hip ratio; RR: relative risk; ↓: decrease; ↑: increase; NP: non-probability (sample)
* Overall effect of PA on adiposity: + Positive effect, 0 No association, - Negative effect, ? Inconclusive

Table 17: Self-reported physical activity & adiposity in adulthood: a summary of cross-sectional studies

Study	Sample	Measure of PA/SB	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect* PA	Overall Effect* SB
FINRISK (Lahti-Koski *et al.* 2002)	11,857 M & 12,747 F (25-64 years); probability sample	Occupational (light or heavy), active commuting (yes/no), LTPA (duration & frequency)	Measured height & weight (BMI)	Treated as a continuous variable & obese≥30kg/m^2	M: Heavy occupational PA & medium & high LTPA ↓ odds of obesity; active commuting & mins of weekly LTPA not associated with obesity	Age, education, diet, tea & coffee, alcohol, smoking, perceived health status	?	N/A
					F: Heavy occupational PA ↑ odds of obesity; active commuting & medium or high LTPA ↓ odds of obesity; mins of LTPA not associated with obesity		?	N/A
German CVPS (Helmert *et al.* 1994)	7663 M & 7722 F (25-69 years); probability sample	Mins in moderate & vigorous sport activities (excludes walking, cycling & gardening)	Measured height & weight (BMI)	Obese≥30kg/m^2	M: ↑ duration of sport activities associated with ↑ BMI (relatively small differences)	Nil	?	N/A
					F: ↑ duration of sport activities associated with ↑ BMI		-	N/A
Europe (Martinez-Gonzalez *et al.* 1999)	15,239 M & F (15+ years); probability sample							

Study	Sample	Measure of PA/SB	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect*	
							PA	SB
Spanish NHS (Gutierrez-Fisac *et al.* 2002)	6,246 M & 5,949 F (20-60 years); probability sample	Type of activity at work & leisure	Self-reported height & weight (BMI)	Obese≥30kg/m^2	M: No association between work PA & BMI or obesity; inverse association between LTPA & BMI; trend for ↓ odds of obesity with ↑ LTPA F: No association between work PA & BMI or obesity; inverse association between LTPA & BMI; trend for ↓ odds of obesity with ↑ LTPA	Age, education, smoking, alcohol, municipality size, chronic disease, perceived health status	- -	N/A N/A
German CVPS (Mensink *et al.* 1997)	5,943 M & 6,039 F (25-69 years); probability sample	Frequency & duration of 18 leisure activities in the past 3 months (adapted Minnesota LTPA Questionnaire)	Measured height & weight (BMI)	Treated as a continuous variable	M: Low & high intensity PA associated with lower BMI; BMI ↓ with ↑ sport frequency, but not duration or intensity F: Low, moderate & high intensity PA associated with lower BMI; BMI ↓ with ↑ sport frequency, but not duration or intensity	Age, smoking, SES, residence, temperature, survey period, liquid index, fat intake, alcohol, work PA	- -	N/A N/A
AusDiab (Cameron *et al.* 2003)	5,049 M & 6,198 F (≥25 years) probability sample (stratified cluster sample)	Walking, moderate & vigorous PA; past week hours of TV viewing (Active Australia Survey)	Measured height & weight (BMI); WC	Obese ≥30kg/m^2; WC≥102cm in men & WC≥88cm in women	M: Highest quintile of PA had lower odds of obesity defined by WC but not BMI; highest quintile of TV viewing had highest odds of obesity defined by BMI or WC F: Highest quintile of PA had lower odds of obesity defined by BMI or WC; highest quintile of TV viewing had highest odds of obesity defined by BMI or WC	Age, smoking, education, country of birth, income, occupation	- -	+ +

Study	Sample	Measure of PA/SB	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect*	
							PA	SB
Australia (Bauman *et al.* 1991)	3,361 M & 3,453 F (25-64 years); probability sample	Frequency of vigorous PA & participation in moderate PA & walking in past 2 weeks	Measured height & weight (BMI)	Obese≥30kg/m^2	M: Greatest proportion of owt & obese in inactive category & greatest proportion of normal wt in most active category	Age, education, region	-	N/A
					F: Greatest proportion of owt & obese in the inactive category & greatest proportion of normal wt in most active category; BMI ↓ with ↑ PA		-	N/A
USA (Tucker *et al.* 1989)	6,138 M (≥19 years); NP worksite sample	Weekly time TV viewing	Thigh, chest & abdomen skinfolds	Obesity≥21 & <30% BF; super-obese≥31 % BF	Watching more than 3hrs TV per day was associated with ↑ odds of obesity & super-obesity	Age, smoking, work hours per week, fitness	N/A	+
Switzerland (Bernstein *et al.* 2004)	2,888 M & 2,869 F (35-74 years); probability sample	Frequency & duration of 70 activities (moderate & high intensity)	Measured height & weight (BMI)	Owt: BMI ≥25kg/m^2 & <30kg/m^2; obese: BMI ≥30kg/m^2	M: Those in the lowest category of vigorous, but not moderate PA, had ↑ odds of owt & obesity	Age, education, country of birth, smoking, alcohol, fat intake, fibre intake	-	N/A
					F: Those in the lowest & middle category of vigorous PA had ↑ odds of owt; those in lowest category of vigorous PA had ↑ odds of obesity; those in lowest category of moderate PA had ↓ odds of owt, but no association with obesity		-	N/A

Study	Sample	Measure of PA/SB	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect*	
							PA	SB
US NHANES III (King *et al.* 2001)	2,618 M & 2,271 F (≥20 years); probability sample	Frequency of LTPA, other exercises, sports or physical hobbies in past month; work PA	Measured height & weight (BMI)	Obese: BMI ≥30kg/m^2	Likelihood of obesity associated with LTPA & work PA	Age, gender, race-ethnicity, SES, smoking, alcohol, urbanisation classification	-	N/A
USA (Tucker *et al.* 1991)	4,771 F (≥19 years); NP worksite sampel	Weekly time TV viewing	Thigh, triceps & iliac crest skinfolds	Obesity: BMI ≥30% BF	Watching more than 2hrs TV per day was associated with ↑ odds of obesity & super-obesity	Age, education, smoking, work week, exercise duration	N/A	+
Stanford Five-City Project (Sallis *et al.* 1986)	1,870 M & 2,161 F (20-74 years); probability sample	Moderate intensity activities (climbing stairs, active commuting, walking)	Measured height & weight (BMI)	Treated as a continuous variable	M: BMI higher in those less active at age 20-49 years, but not 50-74 years	Education	-	N/A
					F: BMI higher in those less active at all ages		-	N/A
China (Hu *et al.* 2002)	2,002 M & 1,974 F (15-69 years); probability sample	Frequency & duration of LTPA, occupational & commuting PA	Measured height & weight (BMI)	Owt: BMI ≥25kg/m^2	M: Increased leisure PA & commuting + leisure PA reduce odds of owt	Age, education, smoking, alcohol, work PA	-	N/A
					F: No difference in odds of owt between different levels of PA		0	N/A

Study	Sample	Measure of PA/SB	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect*	
							PA	SB
Australia (Salmon *et al.* 2000)	1,555 M & 1,837 F (≥18 years); probability sample	Hours of TV viewing; duration & frequency of walking, moderate & vigorous PA	Self-reported height & weight (BMI)	Owt: BMI $\geq 25 kg/m^2$	Those in the inactive category had ↑ odds of owt; watching more than 1hr/day of TV was associated with ↑ odds of owt. When stratified by PA category, those who watched the most TV had the highest odds of owt, even in the high active group	Age, sex, education	-	+
USA (Liebman *et al.* 2003)	928 M & 889 F (≥18 years); probability sample	Frequency of participation in PA of more than 30 mins duration; TV viewing hours	Self-reported height & weight (BMI)	Owt: BMI $\geq 25 kg/m^2$ & $<30 kg/m^2$; obese: BMI $\geq 30 kg/m^2$	TV viewing, but not PA, associated with owt & obesity	Nil	0	+
NHLBI Family Heart Study (Kronenberg *et al.* 2000)	816 M & 962 F (34-62 years); probability sample	Duration & frequency of vigorous, moderate & light PA (adapted from CARDIA)	Self-reported height & weight (BMI)	Owt: BMI>85^{th} percentile (NHANES II)	M: No difference in odds of owt between PA quartiles; ↑ odds of owt in highest quartile of TV viewing F: ↓ odds of owt in highest two quartiles of LTPA; ↑ odds of owt in highest quartile of TV viewing	Age, education, alcohol, income, smoking, & work PA	0 -	+ +

Study	Sample	Measure of PA/SB	Measure of Adiposity	Definition of Owt/Obesity	Significant Findings	Adjustments	Overall Effect* PA	SB
Spain (Vioque *et al.* 2000)	814 M & 958 F (≥15 years); probability sample	Work & LTPA; hours of TV viewing	Measured height & weight (BMI)	Obese: BMI ≥30kg/m^2	Regular sport & LTPA not associated odds of obesity; most active at work had ↓ odds of owt; more than 2 hrs/day TV viewing ↑ odds of owt	Sex, age, population size, marital status, education, sleep time, smoking, TV viewing & PA	?	+
USA (Folsom *et al.* 1985)	738 M & 878 F (25-74 years); probability sample	Past year LTPA, vigorous work PA in past year (Minnesota LTPA Questionnaire)	Measured height & weight (BMI)	Treated as a continuous variable	M: Heavy intensity PA weakly correlated with BMI, but not total PA	Age	?	N/A
					F: Heavy intensity PA weakly correlated with BMI, but not total PA		?	N/A
North/South Ireland (McCarthy *et al.* 2002)	1.379 M & F (18-64 years); probability sample	PA, work, recreation, TV viewing	Measured height & weight (BMI)	Owt: BMI ≥25kg/m^2 & <30kg/m^2; obese: BMI ≥30kg/m^2	Obese participants spent more time in TV viewing & less time in vigorous recreational activities than non-obese participants; there was no difference in total time in recreational activities across categories of BMI	Nil	?	+
Australia (Ball *et al.* 2001)	559 M & 496 F (18-78 years); probability sample	Past 2 weeks frequency & duration of LTPA; vigorous work or home PA	Measured height & weight (BMI)	Owt: BMI ≥25kg/m^2	M: High LTPA associated with ↑ odds of normal weight; no difference for work & home PA	Age, education levels	-	N/A
					F: Moderate or high LTPA associated with ↑ odds of normal weight; no difference for work & home PA		-	N/A

CVPS: Cardiovascular Prevention Study; NHS: National Health Survey; CARDIA: Coronary Risk Development In Adults; AusDiab: Australian Diabetes, Obesity and Lifestyle Study; NHANES: National Health & Nutrition Examination Survey; NHLBI: National Heart, Lung & Blood Institute; NP: non-probability (sample)

M: male; F: female; PA: physical activity; LTPA: leisure time physical activity; MVPA: moderate to vigorous intensity PA; SB: sedentary behaviour; BMI: body mass index WC: waist circumference; %BF: per cent body fat; ↓: decrease; ↑: increase

* Overall effect of PA on adiposity: + Positive effect, 0 No association, - Negative effect, ? Inconclusive

Appendix 14b

Chapter 4: Additional Data Tables

Table 18: Mean (standard deviation) daily steps of healthy weight[a] & overweight young Australian adults in the CDAH follow-up study, by domain of physical activity & sex

Measure Weight Definitions Based On	Men		Women	
	Healthy Wt (Mean, SD)	Overweight (Mean, SD)	Healthy Wt (Mean, SD)	Overweight (Mean, SD)
BMI	9456.7	8975.4	9281.7	8374.7
	(3647.9)	(3466.1)	(2939.1)	(3181.8)
WC	9413.6	8485.4	9254.9	8247
	(3572.9)	(3374.9)	(3030.2)	(3020.9)

WC: waist circumference

Table 19: Self-reported weekly physical activity of healthy weight[a] & overweight (defined using BMI) young Australian adults in the CDAH follow-up study, by domain of physical activity & sex

	Men (Median (IQR))			Women (Median (IQR))		
	Healthy Wt	Overweight	p[b]	Healthy Wt	Overweight	p[b]
Leisure	110	120	0.29	120	120	0.42
(mins)	(0, 285)	(0, 300)		(20, 25)	(30, 240)	
Leisure	495	640	0.33	556	480	0.51
(METs)	(0, 1,440)	(0, 1638)		(66, 1,299	(99, 1,173)	
Commuting	60	40	0.36	75	45	<0.05
(mins)	(0, 170)	(0, 160)		(0, 175)	(0, 150)	
Commuting	198	132	0.33	247.5	148.5	<0.05
(METs)	(0, 594)	(0, 594)		(0, 577.5	(0, 495)	
Household/	130	180	0.10	220	250	0.14
Yard (mins)	(40, 360)	(40, 480)		(75, 570	(90, 710)	
Household/	480	720	0.10	720	860	0.12
Yard (METs)	(130, 1,350)	(140, 1,920)		(240, 1,980)	(270, 2,410)	
Work PA	250	200	0.37	0	0	0.59
(mins)	(0, 1,740)	(0, 2,040)		(0, 330)	(0, 380)	
Work PA	900	876	0.33	0	0	0.61
(METs)	(0, 7,656)	(0, 9,600)		(0, 1,440)	(0, 1,653)	
Total PA	4,441	5,089.5	0.38	3,060	2,958	0.45
(METs)	(2,052, 12,510)	(2,049, 13,920)		(1,450, 5,850)	(1,482, 7,256)	

[a] Healthy weight defined as BMI<25kg/m^2

[b] p-values derived from Kruskal-Wallis test

Table 20: Self-reported weekly physical activity of healthy weight[a] & overweight (defined using waist circumference) young Australian adults in the CDAH follow-up study, by domain of physical activity & sex

	Men (Median (IQR))			Women (Median (IQR))		
	Healthy Wt	Overweight	p[b]	Healthy Wt	Overweight	p[b]
Leisure (mins)	135 (20, 300)	90 (0, 255)	<0.05	120 (30, 240)	115 (10, 230)	0.19
Leisure (METs)	657 (66, 1,638)	408 (0, 1,320)	<0.05	546 (99, 1,260)	469.5 (33, 1,187)	0.19
Commuting (mins)	55 (0, 180)	30 (0, 140)	0.19	65 (0, 168)	50 (0, 150)	0.05
Commuting (METs)	198 (0, 660)	99 (0, 462)	0.14	198 (0, 537)	165 (0, 495)	0.05
Household/ Yard (mins)	150 (35, 410)	180 (50, 480)	0.08	210 (60, 540)	300 (90, 720)	<0.01
Household/ Yard (METs)	570 (120, 1,650)	790 (180, 1,980)	0.07	720 (210, 1,800)	1,020 (280, 2,520)	<0.01
Work PA (mins)	292 (0, 1,800)	255 (0, 2,490)	0.11	0 (0, 340)	0 (0, 370)	0.84
Work PA (METs)	792 (0, 8,478)	1,112 (0, 11,520)	0.10	0 (0, 1,544)	0 (0, 1,617)	0.80
Total PA (METs)	4,500 (2,140, 12,846)	5,341.5 (1,712, 14,988)	0.45	3,021 (1,376, 6,015)	2,920 (1,528.5, 7,020)	0.58

[a] Healthy weight defined as waist circumference<102cm in men & <88cm in women
[b] p-values derived from Kruskal-Wallis test

Table 21: Self-reported weekly physical activity of healthy weight[a] & overweight (defined using BMI) young Australian adults in the CDAH follow-up study, by intensity of physical activity & sex

	Men (Median (IQR))			Women (Median (IQR))		
	Healthy Wt	Overweight	p[b]	Healthy Wt	Overweight	p[b]
Walking (mins)	235 (60, 720)	240 (60, 720)	0.96	195 (60, 440)	180 (60, 420)	0.72
Moderate PA (mins)	300 (120, 1,000)	360 (100, 1,080)	0.44	315 (120, 840)	420 (130, 960)	0.17
Vigorous PA (mins)	180 (40, 720)	240 (60, 780)	0.18	60 (0, 210)	60 (0, 230)	0.44
Total PA (mins)	980 (430, 2,595)	1,080 (450, 3,045)	0.40	750 (370, 1,550)	780 (340, 1,920)	0.43

[a] Healthy weight defined as $BMI<25kg/m^2$
[b] p-values derived from Kruskal-Wallis test

Table 22: Self-reported weekly physical activity of healthy weight[a] & overweight (defined using waist circumference) young Australian adults in the CDAH follow-up study, by intensity of physical activity & sex

	Men (Median (IQR))			Women (Median (IQR))		
	Healthy Wt	**Overweight**	**p[b]**	**Healthy Wt**	**Overweight**	**p[b]**
Walking	235	240	0.83	195	180	0.79
(mins)	(60, 720)	(70, 740)		(60, 420)	(60, 435)	
Moderate PA	330	390	0.12	300	420	0.07
(mins)	(90, 1,020)	(140, 1,050)		(120, 840)	(125, 960)	
Vigorous PA	240	240	0.89	60	60	0.58
(mins)	(60, 720)	(100, 870)		(0, 240)	(0, 180)	
Total PA	980	1,225	0.29	742.5	780	0.33
(mins)	(440, 2,700)	(420, 3,240)		(360, 1,593)	(362.5, 1,905)	

[a] Healthy weight defined as waist circumference<102cm in men & <88cm in women
[b] p-values derived from Kruskal-Wallis test

Table 23: Self-reported weekly sedentary behaviours of healthy weight[a] & overweight (defined using BMI) young Australian adults in the CDAH follow-up study, by sex

	Men (Median (IQR))			Women (Median (IQR))		
	Healthy Wt	**Overweight**	**p[b]**	**Healthy Wt**	**Overweight**	**p[b]**
TV Viewing	12	13	0.11	9.5	11	<0.01
(hrs/week)	(6.8, 19)	(7, 20)		(5, 14)	(6.5, 19)	
Sitting	38	37	0.88	33.3	36	0.19
(hrs/week)	(23, 56)	(21, 58)		(20.5, 50)	(22.5, 52.5)	
Computers	11	10	0.65	5	8	0.14
(hrs/week)	(2, 35)	(3, 30)		(1.5, 20.1)	(2, 30)	

*Healthy weight defined as BMI<25kg/m^2
[b] p-values derived from Kruskal-Wallis test

Table 24: Self-reported weekly sedentary behaviours of healthy weight[a] & overweight (defined using waist circumference) young Australian adults in the CDAH follow-up study, by sex

	Men (Median (IQR))			Women (Median (IQR))		
	Healthy Wt	**Overweight**	**p[b]**	**Healthy Wt**	**Overweight**	**p[b]**
TV Viewing	12	14	<0.01	9.5	12	<0.01
(hrs/week)	(7, 19)	(8, 21)		(5, 14)	(7, 19)	
Sitting	37	38.5	0.37	35	36	0.58
(hrs/week)	(21.8, 56)	(21, 58.5)		(21, 51)	(21, 53.5)	
Computers	11	8	0.20	7	7	0.95
(hrs/week)	(2.5, 33)	(3, 26)		(1.5, 30)	(2, 25)	

[a] Healthy weight defined as waist circumference<102cm in men & <88cm in women
[b] p-values derived from Kruskal-Wallis test

Table 25: Ratios of prevalence of healthy weight (defined using waist circumference) & sociodemographic factors in the CDAH follow-up study, by sex

	Men				Women			
	WC<94cm		PR	(95% CI)	WC<80cm		PR	(95% CI)
	%	(n/N)			%	(n/N)		
Occupation Level								
Manager/professional	75.2	(385/512)	1.0	(ref)	69.9	(344/492)	1.0	(ref)
White collar	75.7	(53/70)	1.01	(0.87-1.16)	67.2	(176/262)	0.96	(0.87-1.06)
Blue collar	63.7	(170/267)	**0.85**	**(0.76-0.94)**	68.2	(30/44)	0.98	(0.79-1.20)
Not in labour force	85.7	(24/28)	1.14	(0.97-1.34)	48.6	(69/142)	**0.69**	**(0.58-0.83)**
Education								
University/higher degree	81.8	(283/346)	1.0	(ref)	74.1	(331/447)	1.0	(ref)
Diploma/vocational	64.4	(204/317)	**0.79**	**(0.71-0.87)**	59.0	(135/229)	**0.80**	**(0.71-0.90)**
School only	69.1	(145/210)	**0.84**	**(0.76-0.94)**	57.8	(149/258)	**0.78**	**(0.69-0.87)**
Marital Status[1]								
Single	78.1	(207/265)	1.0	(ref)	67.5	(172/255)	1.0	(ref)
De Facto	68.1	(307/451)	**0.87**	**(0.80-0.95)**	63.0	(317/503)	0.93	(0.84-1.04)
Married	72.5	(103/142)	0.93	(0.82-1.05)	73.2	(109/149)	1.08	(0.95-1.23)
Separated/Divorced	85.7	(12/14)	1.10	(0.88-1.37)	68.6	(24/35)	1.02	(0.80-1.29)
Smoking								
Non-Smoker	72.8	(377/518)	1.0	(ref)	66.9	(352/526)	1.0	(ref)
Occasional Smoker	79.9	(59/74)	1.10	(0.97-1.24)	66.2	(45/68)	0.99	(0.83-1.18)
Daily Smoker	72.3	(102/74)	0.99	(0.89-1.11)	61.0	(86/141)	0.91	(0.79-1.05)
Parity								
No children	-	-	-		72.0	(373/518)	1.0	(ref)
1 child	-	-	-	-	63.0	(97/154)	0.87	(0.77-1.00)
2 children	-	-	-	-	61.8	(136/220)	**0.86**	**(0.76-0.96)**
3+ children	-	-	-	-	49.0	(49/100)	**0.68**	**(0.55-0.84)**
Country of Birth[2]								
Australia	68.7	(491/716)	1.0	(ref)	64.3	(466/725)	1.0	(ref)
Outside Australia	80.4	(45/56)	**1.17**	**(1.02-1.35)**	78.6	(33/42)	**1.22**	**(1.03-1.44)**

PR: unadjusted prevalence ratios
[1] One female participant was a widow but not included in this analyses due to a lack of statistical power
[2] Country of birth data only available for participants aged 9-15 years in the 1985 ASHFS

Table 26: Ratios of prevalence of healthy weight (defined using waist circumference) for women in the CDAH follow-up study categorised by their average physical activity & sedentary behaviour levels

	WC<80cm		**PR**[a]	**(95% CI)**	**Adj. PR**[b]	**(95% CI)**
	%	**(n/N)**				
Daily Steps[c]						
<5,000	39.3	(22/56)	1.0		1.0	
5,000-7,499	64.8	(149/230)	**1.65**	**(1.17-2.32)**	**1.57**	**(1.12-2.19)**
7,500-9,999	64.3	(169/263)	**1.64**	**(1.17-2.30)**	**1.51**	**(1.08-2.10)**
10,000-12,499	73.2	(131/179)	**1.86**	**(1.32-2.61)**	**1.71**	**(1.23-2.38)**
12,500+	76.6	(72/94)	**1.95**	**(1.38-2.75)**	**1.64**	**(1.16-2.30)**
				P_{trend} < 0.01		P_{trend} < 0.01
Self-Reported PA[d]						
Inactive	65.9	(91/138)	1.0		1.0	
Minimally Active	64.5	(238/369)	0.98	(0.85-1.13)	1.01	(0.86-1.18)
Suff. Active (L)	70.0	(201/287)	1.06	(0.92-1.22)	1.06	(0.90-1.25)
Suff. Active (U)	63.1	(125/198)	0.96	(0.82-1.12)	1.00	(0.84-1.19)
				P_{trend} 0.99		P_{trend} = 0.49
TV Viewing						
<1 hr/day	73.4	(218/297)	1.0		1.0	
1-2 hrs/day	67.4	(221/328)	0.92	(0.83-1.02)	0.92	(0.83-1.00)
2-3 hrs/day	63.3	(119/188)	**0.86**	**(0.76-0.98)**	0.84	(0.79-1.00)
3+ hrs/day	50.7	(73/144)	**0.69**	**(0.58-0.82)**	**0.70**	**(0.58-0.83)**
				P_{trend} <0.01		P_{trend} < 0.01
Sitting						
<20 hrs/week	66.5	(141/212)	1.0		1.0	
20-40 hrs/week	66.2	(221/334)	0.99	(0.83-1.12)	1.06	(0.97-1.16)
40-60 hrs/week	66.3	(167/252)	1.00	(0.87-1.13)	0.94	(0.84-1.05)
60+ hrs/week	64.2	(102/159)	0.96	(0.83-1.12)	**0.73**	**(0.62-0.87)**
				P_{trend} = 0.68		P_{trend} < 0.01
Computer Use						
<10 hrs/week	65.8	(348/529)	1.0		1.0	
10-20 hrs/week	62.6	(72/115)	0.95	(0.82-1.11)	0.94	(0.82-1.08)
20-30 hrs/week	67.1	(51/76)	1.02	(0.86-1.21)	0.92	(0.77-1.09)
30+ hrs/week	67.5	(160/237)	1.03	(0.92-1.14)	0.92	(0.82-1.03)
				P_{trend} = 0.62		P_{trend} = 0.05

[a] PR: unadjusted prevalence ratios
[b] Adj. PR: prevalence ratios adjusted for age at baseline, occupation, education & parity
[c] Average daily steps categorised according to public health cutpoints defined by Tudor-Locke et al (Tudor-Locke *et al.* 2004)
[d] Minutes of self-reported physical activity categorised according to IPAQ-L scoring protocol (reference?)

Table 27: Ratios of prevalence of healthy weight (defined using BMI) for adults in the CDAH follow-up study according to their cardiorespiratory fitness & daily steps

	BMI<25kg/m²		**PR[a]**	**(95% CI)**	**Adj.**	**(95% CI)**
	%	**(n/N)**			**PR[b]**	
Low PA-Low Fitness	39.6	(74/187)	1.0		1.0	
Low PA-Med Fitness	46.7	(77/164)	1.24	(0.98-1.56)	1.11	(0.84-1.47)
Low PA-High Fitness	50.4	(57/113)	1.30	(1.00-1.66)	1.25	(0.94-1.68)
Med PA-Low Fitness	41.5	(68/164)	1.07	(0.84-1.38)	1.02	(0.75-1.39)
Med PA-Med Fitness	54.5	(91/167)	**1.36**	**(1.09-1.69)**	**1.29**	**(1.01-1.66)**
Med PA-High Fitness	51.8	(73/141)	**1.36**	**(1.08-1.71)**	1.18	(0.91-1.54)
High PA-Low Fitness	50.0	(67/134)	**1.29**	**(1.02-1.63)**	1.26	(0.96-1.66)
High PA-Med Fitness	51.3	(77/150)	**1.36**	**(1.09-1.71)**	**1.30**	**(1.01-1.67)**
High PA-High Fitness	63.0	(133/211)	**1.56**	**(1.28-1.91)**	**1.39**	**(1.08-1.78)**

[a] PR: prevalence ratios adjusted for sex
[b] Adj. PR: prevalence ratios adjusted for sex, age, occupation, highest level of education, marital status, country of birth

Table 28: Ratios of prevalence of healthy weight (defined using waist circumference) for adults in the CDAH follow-up study according to their cardiorespiratory fitness & daily steps

	WC<80 (F) &<94cm (M)		**PR[a]**	**(95% CI)**	**Adj.**	**(95% CI)**
	%	**(n/N)**			**PR[b]**	
Low PA-Low Fitness	57.1	(109/191)	1.0		1.0	
Low PA-Med Fitness	64.1	(107/167)	1.11	(0.93-1.31)	1.01	(0.82-1.24)
Low PA-High Fitness	73.7	(84/114)	**1.29**	**(1.09-1.51)**	**1.25**	**(1.04-1.50)**
Med PA-Low Fitness	58.2	(96/165)	1.01	(0.85-1.21)	0.96	(0.77-1.21)
Med PA-Med Fitness	74.4	(125/168)	**1.32**	**(1.13-1.53)**	**1.26**	**(1.05-1.50)**
Med PA-High Fitness	77.8	(112/144)	**1.35**	**(1.17-1.57)**	**1.26**	**(1.06-1.51)**
High PA-Low Fitness	66.4	(89/134)	1.15	(0.97-1.37)	1.18	(0.96-1.45)
High PA-Med Fitness	74.2	(112/151)	**1.28**	**(1.10-1.50)**	**1.25**	**(1.04-1.49)**
High PA-High Fitness	84.1	(180/214)	**1.48**	**(1.29-1.69)**	**1.41**	**(1.19-1.66)**

[a] PR: prevalence ratios adjusted for sex
[b] Adj. PR: prevalence ratios adjusted for sex, age, occupation, highest level of education, marital status, country of birth

Table 29: Ratios of prevalence of healthy weight (defined using BMI) for adults in the CDAH follow-up study according to their cardiorespiratory fitness & self-reported physical activity

	BMI<25kg/m²		**PR[a]**	**(95% CI)**	**Adj.**	**(95% CI)**
	%	**(n/N)**			**PR[b]**	
Low PA-Low Fitness	44.6	(83/186)	1.0		1.0	
Low PA-Med Fitness	54.1	(106/196)	1.19	(0.98-1.44)	0.99	(0.79-1.24)
Low PA-High Fitness	56.1	(88/157)	1.20	(0.98-1.46)	1.04	(0.83-1.30)
Med PA-Low Fitness	47.0	(79/168)	1.01	(0.81-1.26)	1.02	(0.80-1.31)
Med PA-Med Fitness	45.9	(72/157)	1.03	(0.83-1.29)	0.91	(0.71-1.17)
Med PA-High Fitness	62.0	(137/221)	**1.34**	**(1.12-1.60)**	1.19	(0.98-1.45)
High PA-Low Fitness	36.5	(77/211)	0.81	(0.65-1.03)	0.70	(0.54-0.92)
High PA-Med Fitness	49.3	(103/209)	1.10	(0.90-1.34)	1.02	(0.83-1.26)
High PA-High Fitness	51.0	(103/202)	1.17	(0.96-1.43)	1.00	(0.80-1.26)

[a] PR: prevalence ratios adjusted for sex
[b] Adj. PR: prevalence ratios adjusted for sex, age, occupation, education, marital status, country of birth & parity

Table 30: Ratios of prevalence of healthy weight (defined using waist circumference) for adults in the CDAH follow-up study according to their cardiorespiratory fitness & self-reported physical activity

	WC<80 (F) &<94cm (M)		**PR[a]**	**(95% CI)**	**Adj.**	**(95% CI)**
	%	**(n/N)**			**PR[b]**	
Low PA-Low Fitness	60.3	(114/189)	1.0		1.0	
Low PA-Med Fitness	73.2	(145/198)	1.22	(1.06-1.41)	1.07	(0.89-1.29)
Low PA-High Fitness	77.3	(126/163)	**1.30**	**(1.13-1.50)**	1.17	(0.99-1.39)
Med PA-Low Fitness	61.0	(103/169)	1.02	(0.86-1.21)	0.98	(0.80-1.19)
Med PA-Med Fitness	71.1	(113/159)	**1.19**	**(1.02-1.38)**	1.12	(0.94-1.34)
Med PA-High Fitness	82.3	(184/222)	**1.39**	**(1.22-1.58)**	**1.26**	**(1.07-1.47)**
High PA-Low Fitness	57.9	(124/214)	0.97	(0.82-1.14)	0.88	(0.71-1.08)
High PA-Med Fitness	65.2	(137/210)	1.08	(0.93-1.26)	0.98	(0.81-1.18)
High PA-High Fitness	76.4	(155/203)	**1.26**	**(1.10-1.45)**	1.15	(0.97-1.36)

[a] PR: prevalence ratios adjusted for sex
[b] Adj. PR: prevalence ratios adjusted for sex, age, occupation, education, marital status, country of birth & parity

Table 31: Ratios of prevalence of healthy weight (defined using BMI) for adults in the CDAH follow-up study according to their cardiorespiratory fitness & self-reported television viewing

	BMI<25kg/m^2		**PR[a]**	**(95% CI)**	**Adj.**	**(95% CI)**
	%	**(n/N)**			**PR[b]**	
High TV-Low Fitness	35.9	(70/195)	1.0		1.0	
Med TV-Low Fitness	47.4	(91/192)	**1.34**	**(1.06-1.69)**	**1.34**	**(1.01-1.77)**
Low TV-Low Fitness	43.8	(78/178)	**1.30**	**(1.02-1.66)**	1.28	(0.95-1.74)
High TV-Med Fitness	47.0	(77/164)	**1.37**	**(1.08-1.74)**	1.27	(0.95-1.70)
Med TV-Med Fitness	51.3	(102/199)	**1.45**	**(1.16-1.81)**	**1.42**	**(1.09-1.85)**
Low TV-Med Fitness	51.3	(102/199)	**1.48**	**(1.18-1.84)**	1.32	(0.99-1.76)
High TV-High Fitness	49.0	(71/145)	**1.44**	**(1.13-1.83)**	**1.35**	**(1.01-1.81)**
Med TV-High Fitness	57.0	(118/207)	**1.57**	**(1.26-1.95)**	**1.37**	**(1.06-1.78)**
Low TV-High Fitness	61.0	(139/228)	**1.74**	**(1.41-2.14)**	**1.19**	**(1.09-1.30)**

[a] PR: prevalence ratios adjusted for sex
[b] Adj. PR: prevalence ratios adjusted for sex, age, occupation, education, marital status & country of birth

Table 32: Ratios of prevalence of healthy weight (defined using waist circumference) for adults in the CDAH follow-up study according to their cardiorespiratory fitness & television viewing

	WC<80 (F) &<94cm (M)		**PR[a]**	**(95% CI)**	**Adj.**	**(95% CI)**
	%	**(n/N)**			**PR[b]**	
High TV-Low Fitness	53.9	(105/195)	1.0		1.0	
Med TV-Low Fitness	64.8	(127/196)	**1.20**	**(1.01-1.41)**	1.21	(0.98-1.48)
Low TV-Low Fitness	60.2	(109/181)	1.10	(0.93-1.32)	1.16	(0.94-1.45)
Med TV-Med Fitness	66.7	(134/201)	**1.20**	**(1.02-1.43)**	1.18	(0.96-1.46)
High TV-Med Fitness	65.3	(109/167)	**1.23**	**(1.05-1.45)**	1.20	(0.99-1.47)
Low TV-Med Fitness	76.4	(152/199)	**1.41**	**(1.21-1.64)**	**1.39**	**(1.16-1.68)**
High TV-High Fitness	71.2	(104/146)	**1.31**	**(1.11-1.55)**	**1.27**	**(1.04-1.55)**
Med TV -High Fitness	78.0	(163/209)	**1.46**	**(1.26-1.69)**	**1.43**	**(1.20-1.71)**
Low TV-High Fitness	85.0	(198/233)	**1.56**	**(1.36-1.80)**	**1.17**	**(1.10-1.24)**

[a] PR: prevalence ratios adjusted for sex
[b] Adj. PR: prevalence ratios adjusted for sex, age, occupation, education, marital status & country of birth

Appendix 15

Chapter 5: Additional Data Tables

Table 33: Correlation[a] between measures of adiposity in childhood & adulthood in the CDAH follow-up study, by sex & age

Sex	Childhood Age (years)	Measure of Adiposity			
		BMI		WC	
		n	*r*	n	*r*
Males	9	111	0.58**	111	0.37**
	10	120	0.68**	121	0.60**
	11	126	0.54**	125	0.44**
	12	114	0.64**	114	0.59**
	13	107	0.47**	107	0.32**
	14	132	0.43**	132	0.40**
	15	100	0.30**	100	0.35**
	Overall	982	0.46**	982	0.39**
Females	9	119	0.57**	119	0.42**
	10	115	0.48**	116	0.43**
	11	125	0.56**	123	0.49**
	12	111	0.53**	111	0.55**
	13	96	0.47**	97	0.55**
	14	107	0.53**	107	0.38**
	15	114	0.59**	114	0.42**
	Overall	997	0.51**	997	0.45**

[a] Pearson correlation coefficients on age- & sex-specific ranked data
**p<0.01 *p<0.05
BMI: body mass index; WC: waist circumference

Table 34: Persistence of healthy weight & overweight & obesity from childhood to adulthood using waist circumference to define overweight & obesity in adulthood in the CDAH follow-up study

Childhood Weight Status	Adulthood Weight Status			
	Healthy Weight		Overweight[b]	
	n	%	n	%
Males				
Healthy Weight[a]	667	75.4	218	24.6
Overweight	35	35.7	63	64.3
Females				
Healthy Weight[a]	632	70.0	271	30.0
Overweight	26	27.7	68	72.3

[a] Overweight defined as a BMI greater than the IOTF age & sex-specific cutpoints for overweight in children (Cole *et al.* 2000)
[b] Overweight defined as waist circumference≥94cm in men & ≥80cm in women

Table 35: Weight status of adults according to their weight status as a child in the CDAH follow-up study

Adulthood Weight Status	**Childhood Weight Status**			
	Healthy Weight		**Overweight[b]**	
	n	**%**	**n**	**%**
Males				
Healthy Weight	667	95.0	35	5.0
Overweight[a]	218	77.6	63	22.4
Females				
Healthy Weight	632	96.1	26	4.0
Overweight[a]	271	79.9	68	20.1

[a] Overweight defined as waist circumference≥94cm in men & ≥80cm in women
[b] Overweight defined as a BMI greater than the IOTF age & sex-specific cutpoints for overweight in children (Cole *et al.* 2000)

Table 36: Likelihood of being a healthy weight adult (defined using waist circumference) based on childhood waist circumference quintile in males in the CDAH follow-up study, by age

Child Age & WC Quintile	**% HWM**	**(n/N)**	**RR**	**(95% CI)**	**Adj. RR[a]**	**(95% CI)**	**Adj. RR[b]**	**(95% CI)**
9-11 years								
Q1	66.7	(20/30)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Q2	66.0	(35/53)	0.99	(0.85-1.15)	0.99	(0.78-1.25)	0.89	(0.73-1.09)
Q3	54.2	(39/72)	0.90	(0.76-1.06)	**0.73**	**(0.55-0.97)**	**0.72**	**(0.59-0.88)**
Q4	39.6	(44/111)	**0.80**	**(0.68-0.95)**	**0.72**	**(0.55-0.94)**	**0.65**	**(0.51-0.81)**
Q5	18.6	(11/59)	**0.57**	**(0.45-0.72)**	**0.48**	**(0.35-0.68)**	**0.43**	**(0.33-0.58)**
12-13 years								
Q1	66.7	(16/24)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Q2	39.6	(19/48)	**0.80**	**(0.64-0.98)**	0.80	(0.60-1.05)	**0.78**	**(0.61-0.98)**
Q3	48.0	(24/50)	0.88	(0.73-1.05)	0.85	(0.69-1.06)	0.85	(0.68-1.08)
Q4	15.2	(7/46)	**0.76**	**(0.61-0.94)**	0.76	(0.58-1.01)	0.80	(0.60-1.05)
Q5	12.1	(4/33)	**0.49**	**(0.35-0.68)**	**0.49**	**(0.33-0.71)**	**0.47**	**(0.32-0.67)**
14-15 years								
Q1	45.2	(19/42)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Q2	41.5	(17/41)	0.96	(0.77-1.20)	**0.74**	**(0.56-0.98)**	**0.70**	**(0.53-0.92)**
Q3	25.5	(12/47)	0.85	(0.67-1.08)	0.78	(0.59-1.03)	**0.75**	**(0.61-0.94)**
Q4	22.9	(11/48)	**0.69**	**(0.52-0.91)**	**0.58**	**(0.43-0.78)**	**0.53**	**(0.40-0.70)**
Q5	17.2	(5/29)	**0.53**	**(0.37-0.76)**	**0.48**	**(0.33-0.69)**	**0.43**	**(0.30-0.62)**

WC: waist circumference
[a] Adjusted for occupation, highest level of education, marital status
[b] Adjusted for all of the above plus childhood SES & language spoken at home as a child

Table 37: Likelihood of being a healthy weight adult (defined using waist circumference) based on childhood waist circumference quintile in females in the CDAH follow-up study, by age

Child Age & WC Quintile	% HWM	(n/N)	RR	(95% CI)	Adj. RR[a]	(95% CI)	Adj. RR[b]	(95% CI)
9-11 years								
Q1	76.7	(23/30)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Q2	63.3	(19/30)	0.87	(0.67-1.13)	0.82	(0.77-1.09)	0.77	(0.54-1.09)
Q3	76.9	(10/13)	0.84	(0.59-1.18)	0.89	(0.71-1.11)	0.70	(0.44-1.10)
Q4	46.2	(6/13)	**0.59**	**(0.36-0.99)**	**0.62**	**(0.39-0.98)**	**0.54**	**(0.31-0.94)**
Q5	64.9	(144/222)	**0.77**	**(0.64-0.91)**	**0.73**	**(0.62-0.85)**	**0.57**	**(0.39-0.81)**
12-13 years								
Q1	81.5	(53/65)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Q2	73.2	(30/41)	0.87	(0.71-1.05)	0.81	(0.63-1.05)	0.79	(0.57-1.10)
Q3	78.8	(26/33)	0.89	(0.73-1.09)	**0.72**	**(0.55-0.95)**	**0.73**	**(0.53-0.99)**
Q4	48.5	(16/33)	**0.51**	**(0.35-0.75)**	**0.48**	**(0.32-0.71)**	**0.42**	**(0.25-0.70)**
Q5	38.5	(5/13)	**0.33**	**(0.18-0.60)**	**0.24**	**(0.12-0.49)**	**0.17**	**(0.07-0.42)**
14-15 years								
Q1	70.6	(36/51)	1.0	(ref)	1.0	(ref)	1.0	(ref)
Q2	73.8	(31/42)	0.96	(0.77-1.20)	0.86	(0.70-1.06)	0.79	(0.62-1.01)
Q3	57.7	(30/52)	0.79	(0.61-1.01)	**0.73**	**(0.57-0.95)**	**0.70**	**(0.54-0.91)**
Q4	40.6	(13/32)	**0.56**	**(0.37-0.83)**	**0.48**	**(0.31-0.76)**	**0.43**	**(0.28-0.68)**
Q5	26.9	(7/26)	**0.23**	**(0.11-0.45)**	**0.18**	**(0.08-0.41)**	**0.18**	**(0.08-0.40)**

WC: waist circumference
[a] Adjusted for occupation, highest level of education, & number of children
[b] Adjusted for all of the above plus childhood SES & smoking

Appendix 16

Chapter 6: Additional Data Tables

Table 38: Likelihood of being a healthy weight adult (versus being an overweight adult) according to frequency of participation in childhood extracurricular sport in the CDAH follow-up study, by sex & baseline school level

Sex, School Level & No. of Sports	% HWM	(n/N)	RR	(95% CI)	Adj. RR[a]	(95% CI)	Adj. RR[b]	(95% CI)
Males								
Primary School								
0-1 sports	46.3	(44/95)	1.0	(ref)	1.0	(ref)	1.0	(ref)
2 sports	40.4	(42/104)	0.87	(0.63-1.20)	0.82	(0.59-1.13)	0.86	(0.91-1.21)
3 sports	53.3	(41/77)	1.15	(0.85-1.55)	1.12	(0.82-1.52)	1.10	(0.76-1.60)
4+ sports	41.3	(38/92)	0.89	(0.64-1.24)	0.91	(0.65-1.27)	0.97	(0.69-1.36)
Secondary School								
0-1 sports	28.1	(25/89)	1.0	(ref)	1.0	(ref)	1.0	(ref)
2 sports	35.8	(34/95)	1.27	(0.83-1.95)	1.23	(0.79-1.92)	1.41	(0.86-2.31)
3 sports	39.0	(32/82)	1.39	(0.91-2.13)	1.35	(0.87-2.08)	1.33	(0.86-2.05)
4+ sports	27.3	(27/99)	0.97	(0.61-1.54)	0.97	(0.60-1.55)	0.78	(0.46-1.33)
Females								
Primary School								
0-1 sports	67.3	(72/107)	1.0	(ref)	1.0	(ref)	1.0	(ref)
2 sports	65.6	(59/90)	0.97	(0.80-1.19)	0.98	(0.80-1.20)	0.96	(0.80-1.14)
3 sports	65.1	(56/86)	0.97	(0.79-1.19)	0.98	(0.79-1.21)	0.89	(0.74-1.06)
4+ sports	66.2	(45/68)	0.98	(0.79-1.22)	1.02	(0.82-1.27)	0.95	(0.80-1.11)
Secondary School								
0-1 sports	62.9	(56/89)	1.0	(ref)	1.0	(ref)	1.0	(ref)
2 sports	61.7	(58/94)	0.98	(0.78-1.23)	0.98	(0.78-1.23)	1.06	(0.84-1.34)
3 sports	64.9	(50/77)	1.03	(0.82-1.30)	1.06	(0.85-1.33)	1.12	(0.88-1.42)
4+ sports	62.4	(53/85)	0.99	(0.79-1.25)	0.99	(0.79-1.25)	1.02	(0.80-1.30)

HWM: Healthy weight maintainers
[a] Relative risk adjusted for adult physical activity
[b] Relative risk adjusted for adult physical activity plus country of birth, mother's education, highest level of education, marital status & smoking status in males; father's education, highest level of education, marital status & number of children in females

Table 39: Likelihood of being a healthy weight adult (versus being an overweight adult) according to frequency of participation in childhood school sport in the CDAH follow-up study, by sex & baseline school level

Sex, School Level & Frequency of School Sport	% HWM	(n/N)	RR	(95% CI)	Adj. RR[a]	(95% CI)	Adj. RR[b]	(95% CI)
Males								
Primary School								
Never	47.3	(61/129)	1.0	(ref)	1.0		1.0	(ref)
1/week	43.2	(73/169)	0.91	(0.71-1.17	0.92	(0.71-1.20)	0.96	(0.67-1.37)
2/week	33.3	(10/30)	0.71	(0.42-1.21)	0.64	(0.36-1.14)	0.66	(0.34-1.28)
3+/week	52.5	(21/40)	1.11	(0.79-1.57)	1.18	(0.84-1.66)	1.06	(0.71-1.60)
Secondary School								
Never	35.0	(62/177)	1.0	(ref)	1.0		1.0	(ref)
1/week	29.2	(33/113)	0.83	(0.59-1.18)	0.82	(0.57-1.19)	**0.64**	**(0.43-0.96)**
2/week	30.8	(12/39)	0.88	(0.53-1.47)	0.81	(0.48-1.39)	0.67	(0.39-1.18)
3+/week	30.6	(11/36)	0.87	(0.51-1.48)	0.90	(0.51-1.58)	0.56	(0.27-1.15)
Females								
Primary School								
Never	57.5	(73/127)	1.0	(ref)	1.0		1.0	(ref)
1/week	70.9	(95/134)	**1.23**	**(1.03-1.48)**	**1.28**	**(1.06-1.55)**	1.18	(0.96-1.45)
2/week	70.3	(26/37)	1.22	(0.94-1.58)	1.27	(0.98-1.64)	1.20	(0.95-1.52)
3+/week	71.7	(38/53)	1.25	(1.00-1.56)	**1.32**	**(1.06-1.66)**	1.17	(0.92-1.49)
Secondary School								
Never	63.3	(105/166)	1.0	(ref)	1.0		1.0	(ref)
1/week	62.1	(72/116)	0.98	(0.82-1.18)	0.97	(0.80-1.16)	1.07	(0.89-1.30)
2/week	66.7	(26/39)	1.05	(0.82-1.35)	1.04	(0.81-1.34)	0.98	(0.72-1.32)
3+/week	58.3	(14/24)	0.92	(0.65-1.32)	0.89	(0.62-1.27)	0.81	(0.55-1.20)

HWM: Healthy weight maintainers
[a] Relative risk adjusted for adult physical activity
[b] Relative risk adjusted for adult physical activity plus country of birth, mother's education, highest level of education, marital status & smoking status in males; father's education, highest level of education, marital status & number of children in females

Table 40: Likelihood of being a healthy weight adult (versus being an overweight adult) according to duration of childhood school sport in the CDAH follow-up study, by sex & baseline school level

Sex, School Level & Duration of School Sport	% HWM	(n/N)	RR	(95% CI)	Adj. RR[a]	(95% CI)	Adj. RR[b]	(95% CI)
Males								
Primary School								
<30m/wk	45.7	(64/140)	1.0	(ref)	1.0	(ref)	1.0	(ref)
30-59m/wk	50.0	(22/44)	1.10	(0.77-1.55)	1.21	(0.86-1.70)	1.27	(0.92-1.76)
60-89m/wk	38.7	(29/75)	0.85	(0.60-1.19)	0.79	(0.55-1.14)	0.76	(0.49-1.17)
90+m/wk	45.9	(50/109)	1.00	(0.76-1.32)	1.04	(0.79-1.37)	1.07	(0.82-1.41)
Secondary School								
<30m/wk	34.4	(62/180)	1.0	(ref)	1.0	(ref)	1.0	(ref)
30-59m/wk	34.8	(8/23)	1.01	(0.56-1.83)	1.02	(0.54-1.92)	1.01	(0.49-2.07)
60-89m/wk	34.8	(16/46)	1.01	(0.65-1.57)	0.92	(0.57-1.49)	0.67	(0.38-1.16)
90+m/wk	27.6	(332/116)	0.80	(0.56-1.14)	0.81	(0.56-1.17)	0.58	(0.38-0.89)
Females								
Primary School								
<30m/wk	59.9	(82/137)	1.0	(ref)	1.0	(ref)	1.0	(ref)
30-59m/wk	67.6	(25/37)	1.12	(0.87-1.47)	1.17	(0.89-1.52)	1.04	(0.79-1.39)
60-89m/wk	73.9	(51/69)	**1.23**	**(1.01-1.50)**	**1.30**	**(1.07-1.59)**	1.16	(0.94-1.42)
90+m/wk	68.5	(74/108)	1.14	(0.95-1.38)	1.19	(0.98-1.43)	1.15	(0.94-1.41)
Secondary School								
<30m/wk	63.6	(110/173)	1.0	(ref)	1.0	(ref)	1.0	(ref)
30-59m/wk	57.1	(12/21)	0.90	(0.61-1.32)	0.88	(0.60-1.30)	0.94	(0.64-1.39)
60-89m/wk	64.8	(35/54)	1.01	(0.81-1.28)	1.02	(0.81-1.27)	1.14	(0.90-1.44)
90+m/wk	61.9	(60/97)	0.97	(0.80-1.18)	0.94	(0.77-1.14)	0.95	(0.77-1.16)

HWM: Healthy weight maintainers
[a] Relative risk adjusted for adult physical activity
[b] Relative risk adjusted for adult physical activity plus country of birth, mother's education, highest level of education, marital status & smoking status in males; father's education, highest level of education, marital status & number of children in females

Table 41: Likelihood of being a healthy weight adult (versus being an overweight adult) according to frequency of participation in childhood active commuting to & from school in the CDAH follow-up study, by sex & baseline school level

Sex, School Level & Frequency of Active Commuting	% HWM	(n/N)	RR	(95% CI)	Adj. RR[a]	(95% CI)	Adj. RR[b]	(95% CI)
Males								
Primary School								
Never	46.3	(75/162)	1.0	(ref)	1.0	(ref)	1.0	(ref)
1-4/week	46.0	(17/37)	**1.38**	**(1.03-1.85)**	0.94	(0.63-1.40)	0.96	(0.65-1.42)
5-9/week	43.0	(37/86)	1.35	(0.96-1.90)	0.89	(0.65-1.21)	0.83	(0.56-1.22)
10+/week	43.4	(36/83)	**1.45**	**(1.02-2.06)**	0.91	(0.67-1.23)	0.99	(0.70-1.40)
Secondary School								
Never	37.1	(59/159)	1.0	(ref)	1.0	(ref)	1.0	(ref)
1-4/week	25.0	(9/36)	1.17	(0.76-1.82)	0.66	(0.36-1.20)	0.95	(0.54-1.65)
5-9/week	26.4	(23/87)	1.19	(0.80-1.78)	0.67	(0.43-1.03)	0.78	(0.48-1.26)
10+/week	32.5	(27/83)	1.12	(0.63-1.81)	0.88	(0.60-1.27)	0.93	(0.62-1.40)
Females								
Primary School								
Never	63.9	(101/158)	1.0	(ref)	1.0	(ref)	1.0	(ref)
1-4/week	69.1	(29/42)	1.00	(0.84-1.21)	1.04	(0.81-1.33)	1.01	(0.85-1.21)
5-9/week	67.5	(54/80)	1.00	(0.80-1.24)	1.02	(0.84-1.24)	1.00	(0.86-1.17)
10+/week	67.6	(48/71)	0.96	(0.76-1.22)	1.02	(0.83-1.25)	0.94	(0.77-1.14)
Secondary School								
Never	65.2	(103/158)	1.0	(ref)	1.0	(ref)	1.0	(ref)
1-4/week	66.7	(20/30)	0.81	(0.62-1.05)	1.02	(0.78-1.34)	**1.29**	**(1.04-1.61)**
5-9/week	61.3	(38/62)	0.99	(0.82-1.20)	0.94	(0.75-1.18)	0.97	(0.79-1.21)
10+/week	59.0	(56/95)	0.84	(0.65-1.09)	0.87	(0.71-1.07)	0.95	(0.76-1.18)

HWM: Healthy weight maintainers
[a] Relative risk adjusted for adult physical activity
[b] Relative risk adjusted for adult physical activity plus country of birth, mother's education, highest level of education, marital status & smoking status in males; father's education, highest level of education, marital status & number of children in females

Table 42: Likelihood of being a healthy weight adult (versus being an overweight adult) according to duration of childhood active commuting to & from school in the CDAH follow-up study, by sex & baseline school level

Sex, School Level & Duration of Active Commuting	% HWM	(n/N)	RR	(95% CI)	Adj. RR[a]	(95% CI)	Adj. RR[b]	(95% CI)
Males								
Primary School								
<30m/wk	45.6	(94/206)	1.0	(ref)	1.0	(ref)	1.0	(ref)
30-59m/wk	37.7	(23/61)	0.83	(0.58-1.18)	0.79	(0.55-1.14)	0.83	(0.55-1.27)
60-89m/wk	55.3	(21/38)	1.21	(0.88-1.67)	1.17	(0.84-1.63)	1.04	(0.69-1.58)
90+m/wk	42.9	(27/63)	0.94	(0.68-1.30)	0.91	(0.65-1.29)	0.86	(0.54-1.38)
Secondary School								
<30m/wk	34.4	(67/195)	1.0	(ref)	1.0	(ref)	1.0	(ref)
30-59m/wk	27.9	(17/61)	0.81	(0.52-1.27)	0.81	(0.52-1.29)	1.12	(0.67-1.86)
60-89m/wk	25.0	(6/24)	0.73	(0.35-1.49)	0.61	(0.28-1.37)	0.66	(0.31-1.42)
90+m/wk	32.9	(28/85)	0.96	(0.67-1.37)	0.95	(0.66-1.37)	1.02	(0.67-1.56)
Females								
Primary School								
<30m/wk	64.2	(131/204)	1.0	(ref)	1.0	(ref)	1.0	(ref)
30-59m/wk	68.2	(45/66)	1.06	(0.87-1.29)	1.03	(0.85-1.26)	1.04	(0.82-1.31)
60-89m/wk	73.3	(22/30)	1.14	(0.90-1.45)	1.11	(0.86-1.42)	1.19	(0.95-1.50)
90+m/wk	66.7	(34/51)	1.04	(0.83-1.29)	0.98	(0.77-1.24)	0.88	(0.68-1.13)
Secondary School								
<30m/wk	66.7	(122/183)	1.0	(ref)	1.0	(ref)	1.0	
30-59m/wk	67.4	(29/43)	1.01	(0.80-1.28)	0.99	(0.79-1.24)	1.21	(1.00-1.45)
60-89m/wk	47.6	(10/21)	0.71	(0.45-1.13)	0.69	(0.44-1.10)	0.75	(0.45-1.23)
90+m/wk	57.1	(56/98)	0.86	(0.70-1.05)	0.83	(0.68-1.01)	0.86	(0.69-1.06)

HWM: Healthy weight maintainers
[a] Relative risk adjusted for adult physical activity
[b] Relative risk adjusted for adult physical activity plus country of birth, mother's education, highest level of education, marital status & smoking status in males; father's education, highest level of education, marital status & number of children in females

Table 43: Likelihood of being a healthy weight adult (versus being an overweight adult) according to frequency of participation in childhood non-organised physical activity in the CDAH follow-up study, by sex & baseline school level

Sex, School Level & Frequency of Non-Organised PA	% HWM	(n/N)	RR	(95% CI)	Adj. RR[a]	(95% CI)	Adj. RR[b]	(95% CI)
Males								
Primary School								
Never	55.5	(45/99)	1.0	(ref)	1.0	(ref)	1.0	(ref)
1-4/week	42.4	(64/151)	0.93	(0.70-1.24)	0.89	(0.67-1.20)	0.92	(0.66-1.28)
5-9/week	40.3	(31/77)	0.89	(0.63-1.25)	0.86	(0.60-1.22)	0.76	(0.50-1.17)
10+/week	61.0	(25/41)	1.34	(0.97-1.86)	1.20	(0.84-1.71)	1.29	(0.81-2.07)
Secondary School								
Never	29.6	(24/81)	1.0	(ref)	1.0	(ref)	1.0	(ref)
1-4/week	34.7	(60/173)	1.17	(0.79-1.73)	1.28	(0.84-1.97)	1.26	(0.79-2.01)
5-9/week	32.1	(27/84)	1.08	(0.69-1.71)	1.15	(0.70-1.88)	1.19	(0.69-2.04)
10+/week	25.9	(7/27)	0.88	(0.43-1.80)	0.92	(0.42-2.01)	0.73	(0.31-1.72)
Females								
Primary School								
Never	64.1	(59/92)	1.0	(ref)	1.0	(ref)	1.0	(ref)
1-4/week	69.9	(100/143)	1.09	(0.90-1.31)	1.11	(0.92-1.34)	1.01	(0.84-1.21)
5-9/week	61.3	(49/80)	0.96	(0.76-1.20)	0.98	(0.77-1.24)	0.97	(0.77-1.22)
10+/week	66.7	(24/36)	1.04	(0.79-1.37)	1.05	(0.79-1.40)	0.91	(0.67-1.23)
Secondary School								
Never	62.5	(55/88)	1.0	(ref)	1.0	(ref)	1.0	(ref)
1-4/week	62.7	(106/169)	1.00	(0.82-1.22)	0.97	(0.80-1.18)	0.92	(0.74-1.14)
5-9/week	64.6	(42/65)	1.03	(0.81-1.32)	1.01	(0.79-1.28)	0.92	(0.70-1.20)
10+/week	60.9	(14/23)	0.97	(0.68-1.40)	0.91	(0.62-1.33)	1.04	(0.74-1.45)

HWM: Healthy weight maintainers
[a] Relative risk adjusted for adult physical activity
[b] Relative risk adjusted for adult physical activity plus country of birth, mother's education, highest level of education, marital status & smoking status in males; father's education, highest level of education, marital status & number of children in females

Table 44: Likelihood of being a healthy weight adult (versus being an overweight adult) according to duration of childhood non-organised physical activity in the CDAH follow-up study, by sex & baseline school level

Sex, School Level & Duration of Non-Organised PA	% HWM	(n/N)	RR	(95% CI)	Adj. RR[a]	(95% CI)	Adj. RR[b]	(95% CI)
Males								
Primary School								
<60m/wk	45.5	(64/134)	1.0	(ref)	1.0	(ref)	1.0	(ref)
60-149m/wk	44.3	(27/61)	0.97	(0.69-1.36)	0.94	(0.67-1.31)	1.08	(0.78-1.49)
150-300m/wk	48.7	(37/76)	1.07	(0.80-1.44)	1.02	(0.75-1.38)	1.05	(0.73-1.50)
300+m/wk	41.2	(40/97)	0.91	(0.67-1.22)	0.82	(0.60-1.13)	0.69	(0.46-1.05)
Secondary School								
<60m/wk	33.0	(32/97)	1.0	(ref)	1.0	(ref)	1.0	(ref)
60-149m/wk	43.5	(30/69)	1.32	(0.89-1.95)	1.42	(0.95-2.13)	1.45	(0.92-2.28)
150-300m/wk	20.3	(15/74)	0.61	(0.36-1.05)	0.66	(0.38-1.14)	0.79	(0.44-1.42)
300+m/wk	32.8	(41/125)	0.99	(0.68-1.45)	1.06	(0.71-1.58)	1.02	(0.66-1.58)
Females								
Primary School								
<60m/wk	65.1	(84/129)	1.0	(ref)	1.0	(ref)	1.0	(ref)
60-149m/wk	73.7	(56/76)	1.13	(0.94-1.36)	1.17	(0.96-1.41)	1.11	(0.90-1.36)
150-300m/wk	62.9	(44/70)	0.97	(0.77-1.20)	0.96	(0.77-1.21)	0.84	(0.66-1.06)
300+m/wk	63.2	(48/76)	0.97	(0.78-1.20)	0.98	(0.79-1.22)	0.76	(0.76-1.17)
Secondary School								
<60m/wk	60.2	(65/108)	1.0	(ref)	1.0	(ref)	1.0	(ref)
60-149m/wk	63.5	(54/85)	1.06	(0.85-1.32)	0.99	(0.79-1.25)	0.96	(0.74-1.25)
150-300m/wk	66.7	(40/60)	1.11	(0.88-1.40)	1.06	(0.83-1.34)	1.07	(0.79-1.44)
300+m/wk	63.0	(58/92)	1.05	(0.84-1.30)	1.02	(0.82-1.27)	0.98	(0.77-1.25)

HWM: Healthy weight maintainers
[a] Relative risk adjusted for adult physical activity
[b] Relative risk adjusted for adult physical activity plus country of birth, mother's education, highest level of education, marital status & smoking status in males; father's education, highest level of education, marital status & number of children in females

Table 45: Likelihood of being a healthy weight adult (versus being an overweight adult) according to duration of childhood total physical activity in the CDAH follow-up study, by sex & baseline school level

Sex, School Level & Duration of Total Physical Activity	% HWM	(n/N)	RR	(95% CI)	Adj. RR[a]	(95% CI)	Adj. RR[b]	(95% CI)
Males								
Primary School								
<3hr/wk	47.3	(52/110)	1.0	(ref)	1.0	(ref)	1.0	(ref)
3-6hr/wk	47.4	(55/116)	0.94	(0.75-1.18)	0.93	(0.73-1.18)	0.97	(0.69-1.36)
6-9hr/wk	40.3	(25/62)	0.80	(0.58-1.10)	0.78	(0.56-1.10)	0.73	(0.46-1.19)
9+hr/wk	41.3	(33/80)	0.82	(0.61-1.09)	0.78	(0.57-1.07)	0.78	(0.51-1.19)
Secondary School								
<3hr/wk	32.3	(20/62)	1.0	(ref)	1.0	(ref)	1.0	(ref)
3-6hr/wk	38.9	(42/108)	1.21	(0.78-1.86)	1.24	(0.79-1.95)	0.84	(0.55-1.28)
6-9hr/wk	27.3	(18/66)	0.85	(0.50-1.44)	0.84	(0.48-1.48)	0.68	(0.42-1.12)
9+hr/wk	29.5	(38/129)	0.91	(0.58-1.43)	0.97	(0.61-1.54)	0.71	(0.46-1.10)
Females								
Primary School								
<3hr/wk	66.1	(74/112)	1.0	(ref)	1.0	(ref)	1.0	(ref)
3-6hr/wk	62.7	(69/110)	0.92	(0.78-1.09)	0.93	(0.79-1.10)	0.97	(0.79-1.19)
6-9hr/wk	70.0	(42/60)	1.03	(0.86-1.24)	0.99	(0.82-1.21)	1.11	(0.87-1.42)
9+hr/wk	68.1	(47/69)	1.00	(0.84-1.20)	1.02	(0.86-1.22)	0.99	(0.79-1.24)
Secondary School								
<3hr/wk	63.2	(48/76)	1.0	(ref)	1.0	(ref)	1.0	(ref)
3-6hr/wk	66.1	(72/109)	1.05	(0.84-1.30)	1.02	(0.82-1.26)	1.02	(0.80-1.30)
6-9hr/wk	58.0	(40/69)	0.92	(0.70-1.20)	0.87	(0.67-1.13)	0.91	(0.68-1.22)
9+hr/wk	62.6	(57/91)	0.99	(0.78-1.25)	0.960	(0.76-1.20)	0.92	(0.71-1.20)

HWM: Healthy weight maintainers
[a] Relative risk adjusted for adult physical activity
[b] Relative risk adjusted for adult physical activity plus country of birth, mother's education, highest level of education, marital status & smoking status in males; father's education, highest level of education, marital status & number of children in females